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Req. No 59196
Iron Ore Recovery, Phase I

MINERALOGICAL EVALUATION OF SAMPLES FROM THE GRINDING AND SPIRAL CIRCUITS OF THE SCULLY CONCENTRATOR

FINAL REPORT

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1.0 INTRODUCTION

This report presents the results of the mineralogical investigation of eight mill products from the Scully Concentrator of Wabush Mines Ltd. and five products of the bench test carried out at the Ontario Research Foundation.

The investigation was sponsored by the Canada Center for Mineral and Energy Technology (CANMET) in Ottawa, in co-operation with Wabush Mines Ltd., Newfoundland under the Canada Newfoundland Mineral Development Agreement.

Technical advice and assistance was provided by Dr. M. Stefanski (Scientific Authority). Dr. W. Petruk of CANMET guided the image analysis program. Their contribution is gratefully appreciated.

The objectives of the investigation were to determine mineral characteristics that affect iron and manganese recoveries in order to improve iron recovery and investigate if possibilities exist to decrease the content of manganese in the concentrate.

A total of thirteen samples were originally received at the Research and Productivity Council from Wabush Mines in June 1986. The investigation of the samples commenced in July 1986.

While the project progressed, two meetings of the parties involved in the project were held at CANMET in Ottawa on June 2, 1987 and October 27, 1987. At these meetings, the up-to-date results of the mineralogical investigation were presented and discussed and recommendations were made with regard to the further procedure. It was recommended that the number of the mill products from the Scully Concentrator be reduced to eight. In exchange, RPC agreed to investigate five samples from the bench test carried out by the Ontario Research Foundation.

1.1 List of the Examined Products

A total of thirteen mill products were examined. Below is the list of the products.

1.1.1 Scully Concentrator

Trommel Screen Undersize (TSU)
Sizing Screen Oversize (SSO)
Sizing Screen Undersize (SSU)
Rougher Spiral Middlings (RSM)
Rougher Spiral Concentrate (RSC)
Rougher Spiral Tailings (RST)
Cleaner Spiral Concentrate (CSC)
Cleaner Spiral Tailings (CST)

1.1.2 ORF Bench Test

Mill Product -20 mesh
Mill Product -28 mesh
Middlings (-28 mesh run)
Concentrate (-28 mesh run)
Tailings (-28 mesh run)

2.0 SAMPLE PREPARATION

2.1 Samples from the Scully Concentrator

Upon receipt, the samples were homogenized and a small split of each was taken for chemical analysis. The remaining portion of each sample, except for the cleaner spiral concentrate, was screened into the following five fractions:

+850 micron
+212 micron
+106 micron
+53 micron
-53 micron

The sample of the cleaner spiral concentrate was sized into the following eight fractions:

+850 micron
+425 micron
+212 micron
+106 micron
+53 micron
+38 micron
-38 micron

One polished grain mount was produced from the fractions minus 850 micron and two or three mounts were prepared from the fraction plus 850 micron. The polished mounts were used for the mineralogical and image analysis of the mineral components of the mill products.

The samples for the chemical analysis were pulverized and the contents of iron, manganese, silica, calcium, magnesium, sodium, potassium, titanium, phosphorus and carbon were determined in each of them. The analysis was performed at RPC.

2.2 Samples from the ORF Bench Test

Each sample from the ORF bench test was sieved into the following four fractions:

+212 micron
+106 micron
+53 micron
-53 micron

One polished grain mount was prepared from each of the sieve fractions.

Chemical analysis of the samples was not performed.

3.0 ANALYTICAL METHODS

3.1 General Remarks

The grain mounts prepared from individual size fractions of each sample were analyzed. The analysis was carried out with an Electron Microprobe and an Automated Image Analyzer. Upon completion of the analysis of all sieve fractions, the data were combined to represent the whole sample.

3.2 Mineral Identification

The grain mounts were examined initially using an optical microscope. The optical examination allowed for preliminary identification of the composition, textures and the range of grain size of the mineral components of the ore particles.

The optical examination was followed by qualitative and quantitative chemical microanalysis of the mineral components of the samples. The microanalysis was performed using the JEOL 733 Electron Probe Micro Analyzer (EPMA).

The information generated by the optical and microprobe investigation was utilized to develop an Automated Image Analysis (AIA) program. The program measured the required parameters of the mineral grains.

The principle of the analysis is that the microprobe generates an image of ore particles in which individual mineral components have different grey levels (brightnesses). The image is then sent to the automated image analyzer which identifies the mineral components on the basis of the grey levels and measures the mineral grain parameters. The grey levels (brightnesses) of minerals are constant for a given chemical composition at given microprobe thresholds.

The microprobe thresholds were set at 20.0 kV for the accelerating voltage and 30.0 nA for the beam current.

Because some of the manganese minerals appeared to have the same grey level as that of the iron oxides, they were identified on the basis of the manganese content. The identification was facilitated by x-ray mapping of the ore particles exposed to the electron beam scanning the surface of a grain mount. The mapping "picked up" only those mineral grains in which concentration of manganese exceeded 5.0 wt%. Subsequently, the parameters of the grains were measured. Moreover, the mapping was able to detect and measure iron oxide grains in which manganese occurs in solid solution with iron. As a result, those of the iron oxides which contained more than 5.0 wt% of manganese were classified as manganese minerals.

3.3 Mineral Phases Measured

It was learned from the microprobe examination of the samples that many of the ore forming minerals had non-stoichiometric compositions (see also Chapter 5.0). Thus, some of these minerals are characterized by a continuous range of grey levels. This is also because of compositional gradations between several mineral components (e.g. goethite grading to limonite).

The above problems were overcome by grouping mineral components into four composite mineral phases. These phases are listed below. The list includes the means by which the phases were identified (grey level or x-ray mapping), average contents of iron, manganese and silica in the phases and the specific gravity of the phases. The specific gravities were assumed based on the values for the individual phase-forming minerals quoted by Ramdohr, 1969 and a visual estimate of the individual mineral quantities in the phases.

Mineral Phase	Identified By	Major Component	Density
Hematite + magnetite	grey level	Fe = 69.0%	5.2
Mn minerals + Mn goethite	x-ray map	Mn = 55.0%	5.1
Goethite free of Mn	grey level	Fe = 46.0%	4.2
Silicates	grey level	Si = 46%	2.6

The contents of iron, manganese and silicon in the phases as well as the specific gravities listed above, have been used for the calculation of phase quantities.

For detailed information on the minerals included in the composite mineral phases, see Chapter 5.0.

3.4 Mineral Grain Parameters Measured by the AIA Program

The samples from the Scully Concentrator and the ORF bench test were analyzed using the same AIA program.

The following three parameters of the mineral phase grains were measured in each grain mount:

1. quantity
2. size
3. liberation

3.4.1 Mineral Quantities

The AIA program measured mineral quantity as an area percent of a total area occupied by all the mineral phases present on the surface of a polished grain mount.

It was assumed that the area percent of a mineral phase is proportional to the volume percent of that phase in a sample.

Using volumetric proportions and specific gravities, the weight proportions of each phase in a grain mount (sieve fraction) and, eventually, sample (combination of sieve fractions) were calculated.

Based on weight proportions and the average chemical composition of the mineral phases, the contents of iron, manganese and silica were calculated for each mill product. The results of the calculations were compared with the assays for these elements performed at RPC and ORF. The comparison revealed very good (almost 100%) correlation between the Fe, Mn and Si grades based on the assays and those based on the mineral quantities for the samples of the spiral concentrates and tailings. The samples of the middlings and feed to the spirals, on the other hand, showed considerable lack of correlation between element concentrations based on the assays and the mineral quantities. Namely, the calculations based on the mineralogical study show consistently more iron and less silica than the assays performed at RPC, the Scully Concentrator and ORF.

It is believed, that the above-mentioned discrepancies result from:

-nonstoichiometric composition of the mineral phases
-actually lower densities of the iron minerals than those assumed after Ramdohr 1969. Some of the iron mineral grains (martite, magnetite) are porous due to the leaching (alteration) processes, with micropores either filled with secondary, low density and low iron minerals (goethite, some of the manganese minerals). These micropores, which are as fine as few micrometers in diameter, could not be measured by the AIA program. As a result, such grains were treated by the AIA program as a single mineral of high density and high iron content.

-insufficient number of grains measured
-sample preparation process

Eventually, the mineral quantities in combined samples were calculated on the basis of the assays and the average chemical composition of the mineral phases determined by microprobe analysis of 40-50 mineral grains of each phase. It was also assumed that the hematite and magnetite/goethite, free of manganese weight ratio was equal to the volumetric ratio of these phases measured by the AIA program in the fractions. During the calculations, all the iron was assigned to the hematite plus magnetite and goethite phases (although some of the silicates and manganese minerals also contain iron), while all the manganese was assumed to form the manganese minerals plus the manganese goethite phase (even though as much as 5.0 wt% of manganese may be present in the hematite plus magnetite phase). The distribution of the mineral phases in individual sieve fractions was calculated using the mineral quantities obtained from the image analysis of the fractions, the contribution of the sieve fractions to the total weight of a sample and total quantities of the minerals in the combined fractions.

3.4.2 Grain Size of Mineral Phases

The grains have been classified into the following size classes:

0.0 - 5.0 micrometer
5.0 - 8.0 micrometer
8.0 - 14.0 micrometer
14.0 - 23.3 micrometer
23.0 - 39.0 micrometer
39.0 - 65.2 micrometer
65.2 - 109.0 micrometer
109.0 - 182.0 micrometer
182.0 - 304.0 micrometer
304.0 - 509.0 micrometer
509.0 - 850 micrometer
plus 850 micrometer

The size of composite ore particles was not determined.

3.4.3 Liberation of the Mineral Phases

The AIA program classified the ore particles based on the area occupied by a mineral phase of interest in the total area of a particle.

Ore particles in which the area occupied by a phase of interest equals or exceeds 85.0% of a total particle area have been classified as free (liberated) grains of that phase. The particles in which the area consumed by a phase of interest ranges from 0.0% to 85.0% have been classified as locked grains of that phase.

Classes of liberation were determined for each of the four composite mineral phases.

Below is the list of the classes of liberation:

0.0 - 5.0%
5.0 - 15.0%
15.0 - 25.0%
25.0 - 35.0%
35.0 - 45.0%
45.0 - 55.0%
55.0 - 65.0%
65.0 - 75.0%
75.0 - 85.0%
85.0 - 95.0% = free grain of phase
plus 95.0% = free grain of phase

4.0 MINERAL COMPONENTS, MINERAL ASSOCIATIONS AND TEXTURES

4.1 General Remarks

Examination of the samples from the grinding circuit indicate that the ore is composed predominantly of hematite and quartz, each occurring in approximately equal quantities. All the other minerals present in the samples do not exceed approximately 15 wt% of the feed to the concentrate in total.

Hematite, quartz and accessory magnetite are the primary minerals in the ore. All the other minerals were formed at the expense of the primary minerals and occur in accessory amounts.

Hematite and quartz are characterized by stoichiometric chemical compositions and, most probably, uniform densities.

The most abundant secondary minerals are goethite, free of manganese, pyrolusite and psilomelane. The secondary minerals and magnetite are characterized by a very unstable "nonstoichiometric" chemical composition. It is believed that the nonstoichiometric compositions are reflected in non-uniform densities of these minerals.

The most typical and abundant texture is coarse, granular aggregates (Figure 1, particles A, B) composed predominantly of quartz and hematite. Upon comminution in the mill, these minerals become highly liberated even in the sieve fraction +20 mesh. The breakdown of the coarse grained aggregates is facilitated by weak bonding between the mineral components due to the leaching of silica along grain boundaries.

Contrary to the major minerals, the secondary phases developed two types of textures:

- coarse grained, massive, often colloform accumulations which supply free grains of the phase to the sieve fractions +65 and even +20 mesh (Figure 1, particle C)
- very fine-grained intergrowths of primary and/or secondary minerals, from which the mineral components cannot be liberated unless the ore is ground to minus 400 mesh (Figure 1, particle D)

The effect of the textural characteristics of the major and accessory minerals manifests itself in:

- normal grain size distribution of the hematite, magnetite and quartz
- high liberation (80% - 99%) of the hematite and quartz in all the mill products studied
- bimodal grain size distribution of the secondary minerals (two maxima of grain size distribution)
- an overall low liberation (40% - 50%) of the secondary minerals in all the mill products studied.

For technical reasons (see Chapter 3) the ore-forming minerals have been grouped into the following four composite mineral phases:

1. hematite and magnetite
2. manganese minerals and manganese goethite
3. goethite free of manganese
4. silicates

The following is a detailed description of the mineral phases.

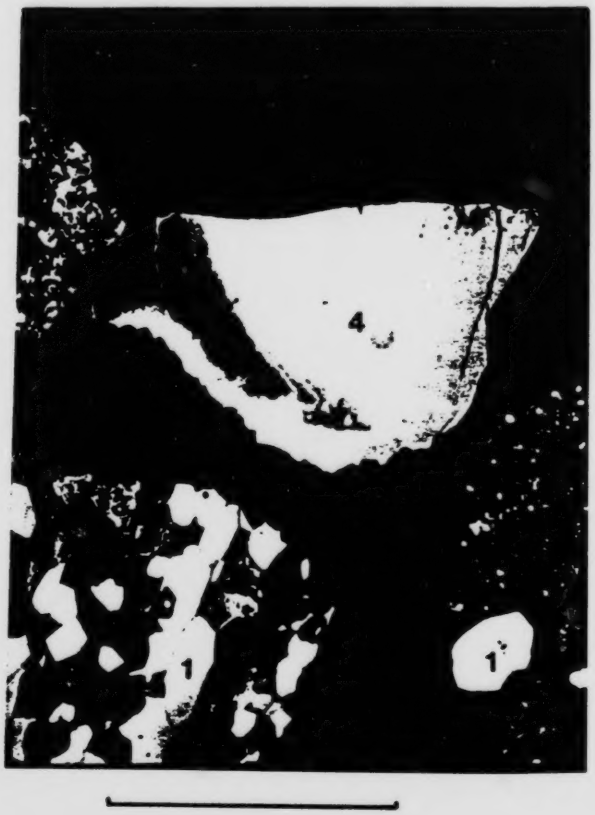


FIGURE 1.

Particle A:	Coarse grained hematite (1) intergrown with quartz (2) and massive goethite (3) after hematite. Most common texture.
Particle B:	Coarse grained hematite (1) intergrown with quartz (2). Quartz is crowded with blebs of hematite.
Particle C:	Massive, coarse (+20 mesh) grain of psilomelane (4) grading into wad (5). Free grain of manganese mineral.
Particle D:	Coarse grained quartz (2) combined with very fine grained intergrowths (6) of magnetite (light grey) and goethite rich in manganese (grey, lighter than quartz).

Optical microscope
Bar Scale = 1.0 mm

4.2 Hematite and Magnetite Phase

In addition to hematite and magnetite, martite has been included into this phase.

Based on the microanalysis of about 50 grains of the minerals included in the phase and their frequency of occurrence, it was assumed that the phase contains 69.0% iron and its density equals 5.2.

It has been visually estimated that hematite comprises about 80% - 90% of the phase. Martite and magnetite constitute the remaining 10% - 20% and appear to occur in approximately equal proportions.

4.2.1 Hematite

Hematite is the major iron-bearing mineral characterized by a uniform chemical composition. Manganese in solid solution with iron was not found in the hematite.

Two forms of the mineral were distinguished:

1. granular
2. tabular (specularite)

The granular hematite (Figure 2) is far more abundant than the specularite (Figure 3). This estimate is based on visual examination of the samples.

The non-liberated hematite occurs in three major mineral associations. They are:

1. Coarse, granular aggregates composed of hematite, quartz and various, but usually low, amounts of secondary minerals (Figure 4).

FIGURE 2. Granular, coarse grained hematite.

Optical microscope
Bar Scale = 0.5 mm

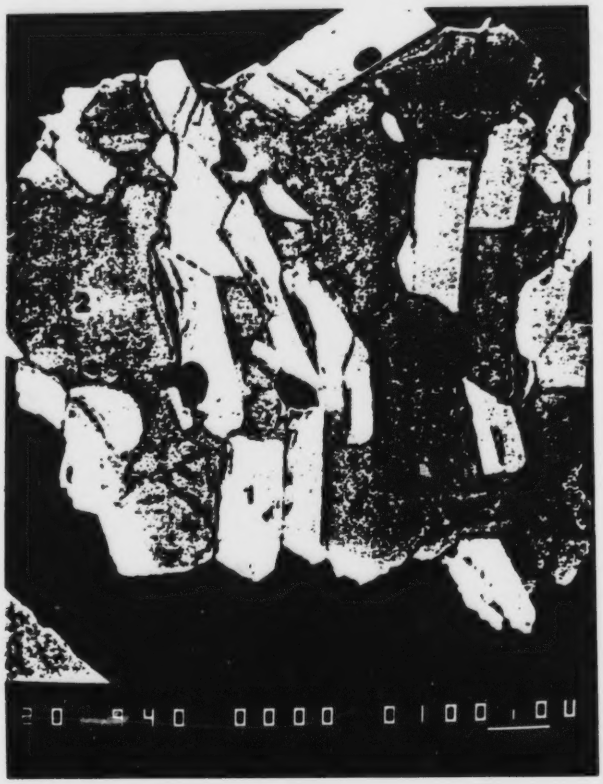


FIGURE 3. Specular hematite (such as 1) embedded in massive goethite (2) characterized by uneven content of iron expressed in various shades of grey. Quartz marked with (3).

Backscattered Electron Image
Bar scale = 10 micrometers

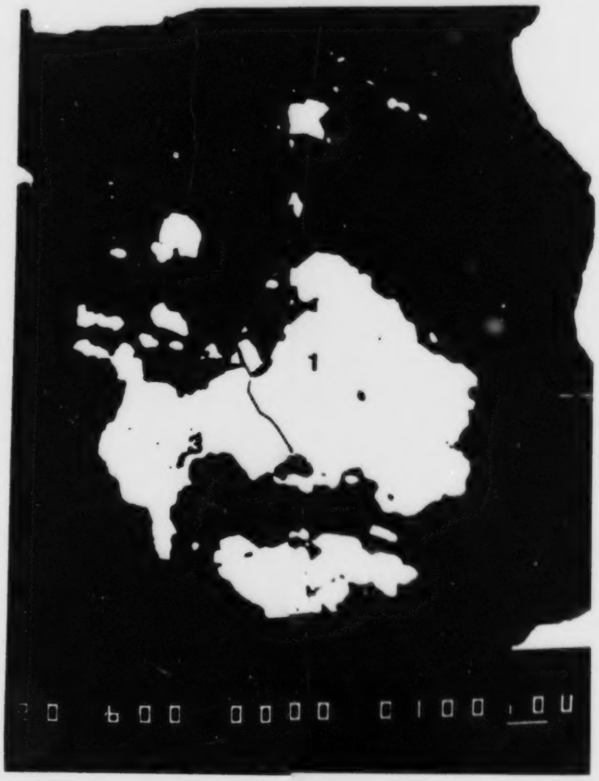


FIGURE 4. Hematite (white, 1) in granular aggregate with quartz (2). Note trace amounts of goethite (light grey, 3).

Backscattered electron image
Bar Scale = 10 micrometers

2. Granular aggregates of hematite replaced to a variable degree by goethite which may be either free of manganese or manganese-rich (Figure 5), see also Figure 3.

3. Inclusions of hematite blebs in quartz (Figure 6), see also Figure 1, particle B.

Parageneses of hematite with manganese minerals were observed very rarely (Figure 7) since most of the unliberated manganese minerals are combined with goethite.

4.2.2 Magnetite

Magnetite is a nonstoichiometric mineral which as a rule contains manganese in solid solution with iron. The concentration of manganese in magnetite was determined by microanalysis of several grains of this mineral. The analysis revealed that the magnetite contains from 0.8% to 7.0% manganese. The iron concentration in the analyzed grains of magnetite ranges from 59.0% - 70.0%, depending on the manganese concentration in a given grain.

During the course of the image analysis the magnetite grains in which manganese content exceeded 5.0% were classified and measured as a manganese mineral phase.

Magnetite shows a tendency to form euhedral grains which invariably are replaced to a certain extent by hematite along crystallographic planes (Figure 8). This type of replacement is called martitization. Less frequently, the magnetite is replaced by goethite which is usually a manganese goethite (Figure 9).

The most important paragenesis of the magnetite is the one with martite and, indirectly, with goethite due to a commonly observed replacement of the martite by goethite.

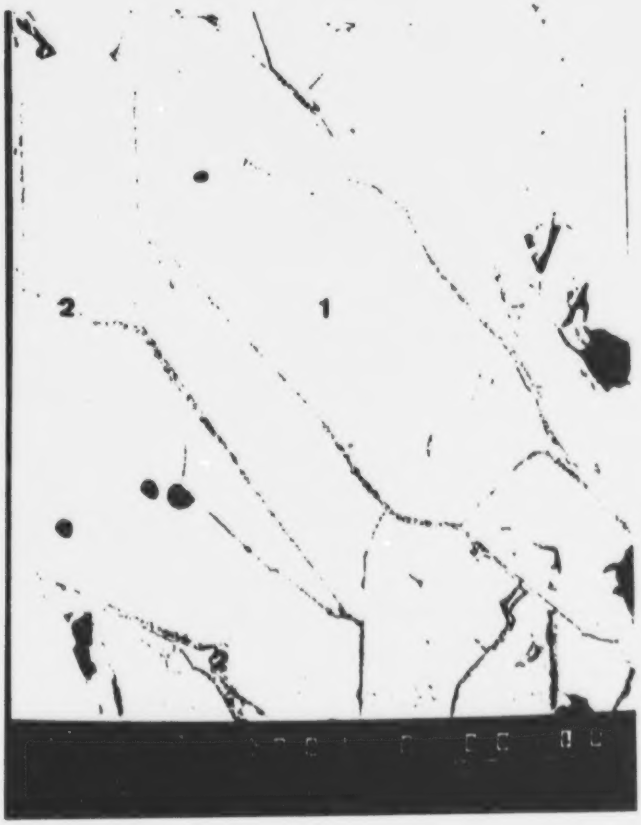


FIGURE 5. Specular hematite (1) replaced by Mn-free goethite along grain boundaries (grey, 2). Note inclusions of quartz in hematite (black).

Backscattered electron image
Bar Scale = 100 micrometers

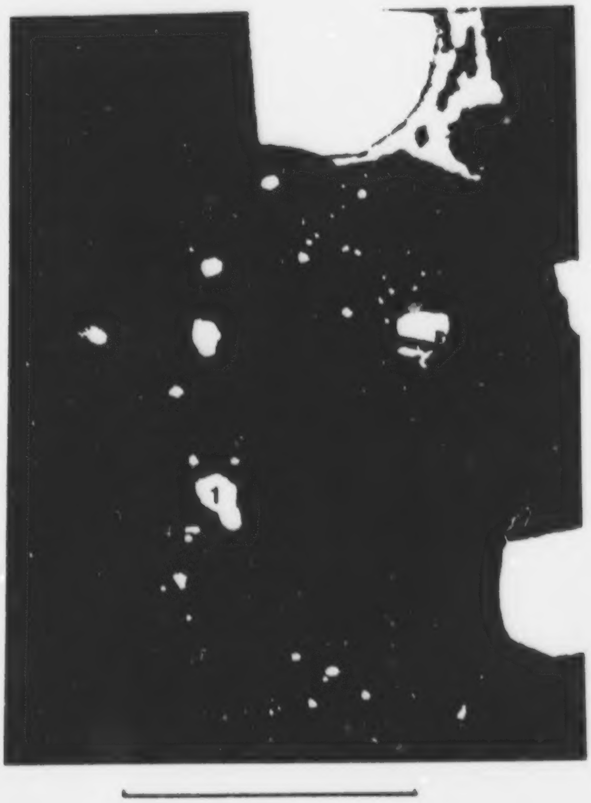


FIGURE 6. Inclusions of hematite (1) in quartz (2).

Optical microscope
Bar Scale = 0.05 mm

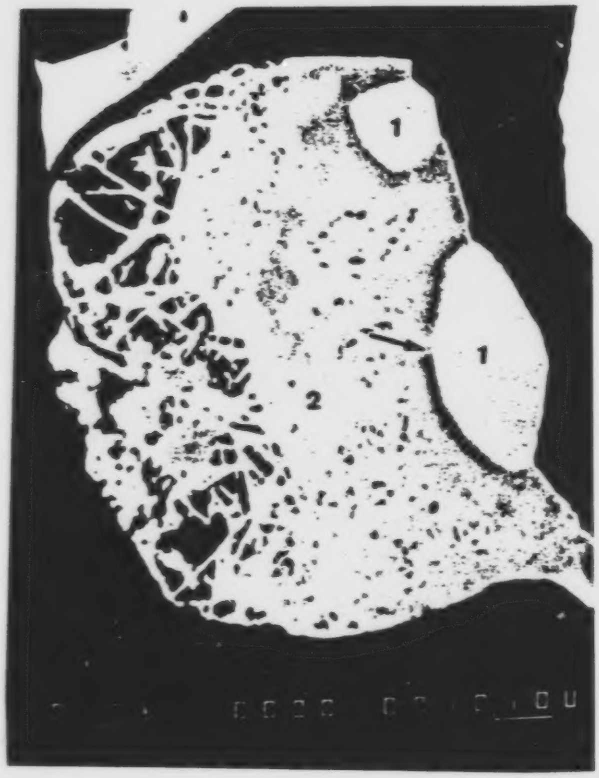


FIGURE 7. Hematite (1) replaced by and intergrown with semicrystalline psilomelane (2) characterized by low manganese contents on the contacts with the hematite and elsewhere (dark grey, arrowed).

Backscattered electron image
Bar Scale = 10 micrometers

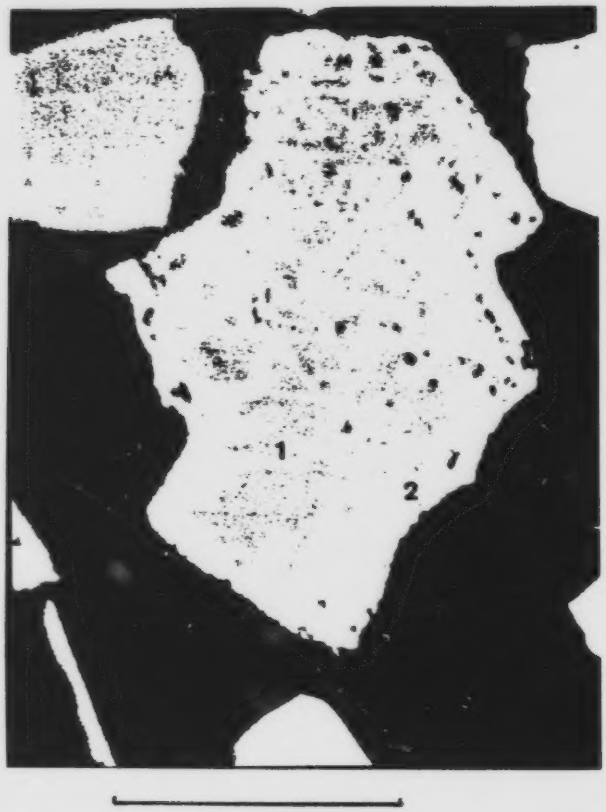


FIGURE 8. Grain of magnetite (dark grey, 1) replaced by martite (2) along crystallographic planes.

Optical microscope
Bar Scale = 0.1 mm

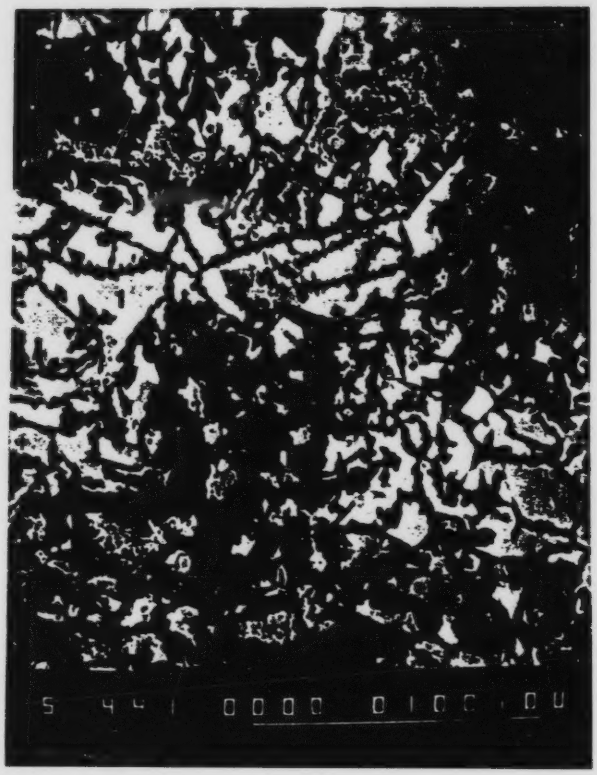


FIGURE 9. Fragment of magnetite grains strongly replaced by goethite. Magnetite is marked with (1), goethite with (2).

Backscattered electron image
Bar Scale = 100 micrometers

4.2.3 Martite

This secondary hematite after magnetite contains, similarly to the magnetite, very unstable amounts of manganese in solid solution. Concentration of manganese in certain martites reaches 10.0%, while the iron content does not exceed 55.0%. Nevertheless, such grains are rather sparse and it has been assumed, that an average iron and manganese contents in this mineral are 68.0% and 1.0% respectively.

The most common associations of the martite are those with magnetite and goethite.

Replacement of magnetite by martite proceeds from the edges of magnetite grains towards their interiors. The process is usually followed by formation of goethite at the expense of the martite and results in the development of a characteristic porous texture of the martite (Figure 10).

Goethite that carries uneven amounts of manganese is usually present in the pores of the martite as very fine grained, very complex intergrowths with the latter (Figure 11).

4.3 Manganese Minerals and Manganese Goethite Mineral Phase

As far as the chemical composition and textures are concerned, this is the most complex phase in the ore.

All the minerals included in this phase are of a secondary origin. As such, they were formed as a result alteration (replacement) of the original hematite and magnetite. The replacement processes are recorded in the textures and the composition of the phase.

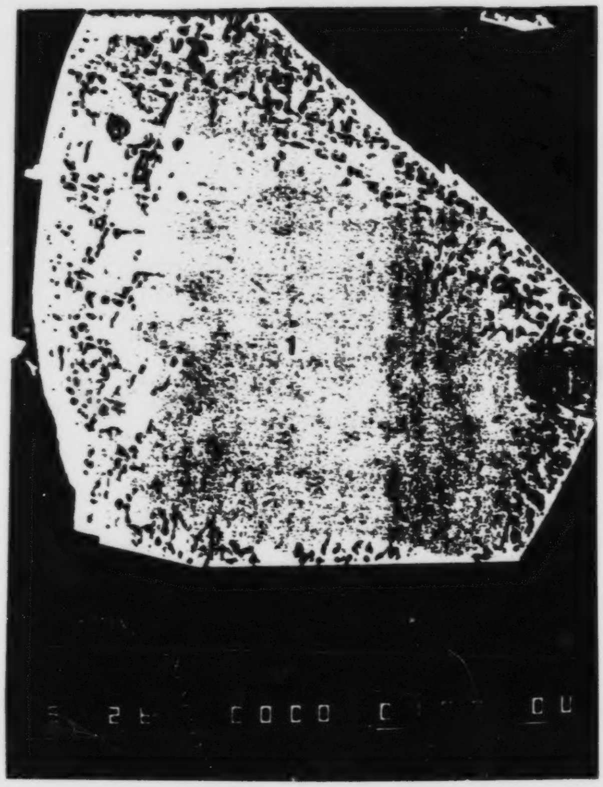


FIGURE 10. Interior of magnetite grain (1) with porous martite (2) developed on edges of the grain.

Backscattered Electron Image
Bar scale = 100 micrometers

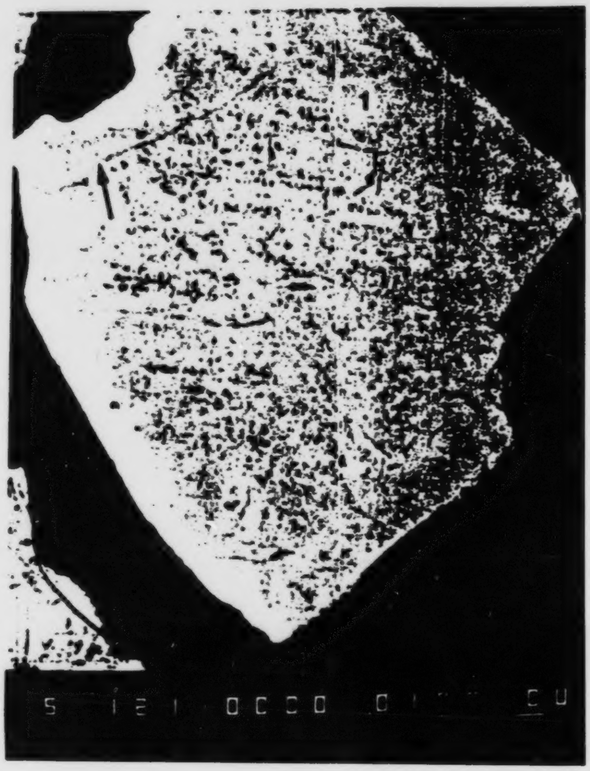


FIGURE 11. Martite (1) dotted with goethite (grey) and limonite (dark grey) after martite. Note veinlets of manganese goethite dissecting the grain (arrowed). (2) marks quartz. Liberation of goethite and manganese goethite from this particle is impossible unless overgrinding (-400 micron grind) is applied.

Backscattered Electron Image
Bar Scale = 100 micrometers

An average density of 5.1 and composition of 55.0% manganese were assumed for the purpose of the mineral quantity calculations. The average concentration of manganese was determined by microanalysis of approximately 40 grains of the phase forming minerals.

4.3.1 Pyrolusite

Pyrolusite is a coarse crystalline form of manganese oxide. As a rule, it occurs as columnar aggregates of crystals separated by dehydration cracks elongated parallel to the length of the aggregates. The mineral grades into and is frequently intergrown with microcrystalline psilomelane and earthy, low manganese wad that contains anywhere from 18.0% to 22.0% Mn (Figure 12). The concentration of this element reaches 68.0%, although pyrolusites containing only 54.0% manganese were also observed.

Most frequently, unliberated pyrolusite was observed as a constituent of large, +20 mesh particles containing various manganese minerals, but its intergrowths with hematite were also found (Figure 13).

Due to the crystalline nature and dehydration, the pyrolusite is believed to have high density of about 5.5 (after Ramdohr 1969). High density strongly influences behaviour of this mineral in the spirals where it tends to pass over to the concentrates together with hematite.

The problem of actual density (or rather ranges of density) of the pyrolusite and other manganese minerals is very important in minimizing the manganese content in the spiral concentrates. If an average density of the manganese minerals is 5.1 (as was assumed for mass balance calculations) they will always tend to enter spiral concentrates together with hematite and magnetite.

4.3.2 Psilomelane

Psilomelane is a microcrystalline mineral which differs from the pyrolusite with substantially higher content of water, lower content of manganese that ranges from 40.0% to 50.0% and the presence of such elements as potassium, barium and silicon. While potassium and silicon were found in several grains of the psilomelane only in trace proportions, the concentration of barium of about 5.0% (semiquantitative data) was recorded in some psilomelanes (Figure 12). The mineral frequently grades into high-manganese pyrolusite and low manganese wad (Figure 13).

The mineral has a tendency to form either coarse accumulations which, upon grinding, supply free grains even to the +20 mesh fraction of the samples (Figure 14), or fine intergrowths with goethite, particularly when goethite replaces hematite and magnetite (Figure 15).

The accumulations of psilomelane are commonly cut by veinlets of psilomelane rich in barium (hollandite) and wad (Figure 16). Colloform psilomelane accompanied by quartz, both formed in voids in presumably brecciated and leached ore, were observed frequently (Figure 17).

It is believed that certain psilomelanes were formed at the expense of goethites and limonites (Figure 18).

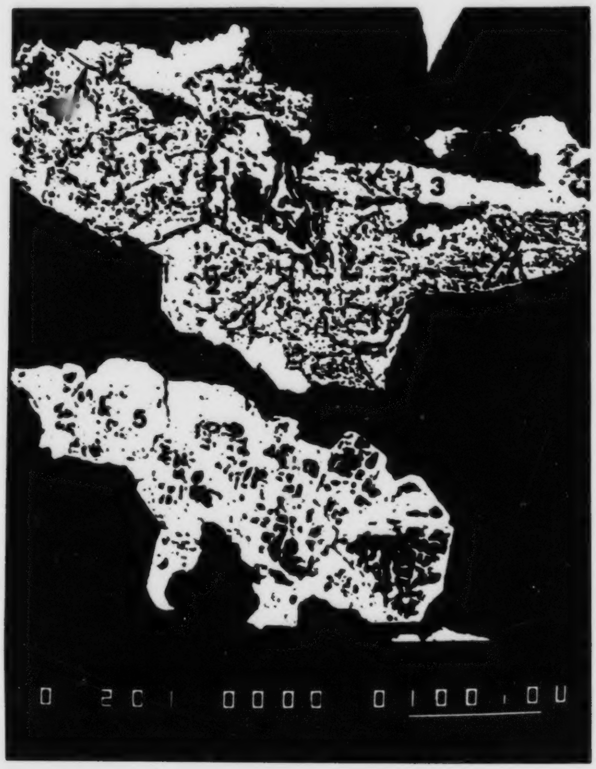


FIGURE 12. Particle composed of manganese oxides. Psilomelane is marked with (1), pyrolusite with (2), barium-rich psilomelane with (3). Wad is (4). Note dehydration cracks in pyrolusite (arrowed). Also note highly porous particle composed of martite (5) and quartz (6).

Backscattered Electron Image
Bar scale = 100 micrometers

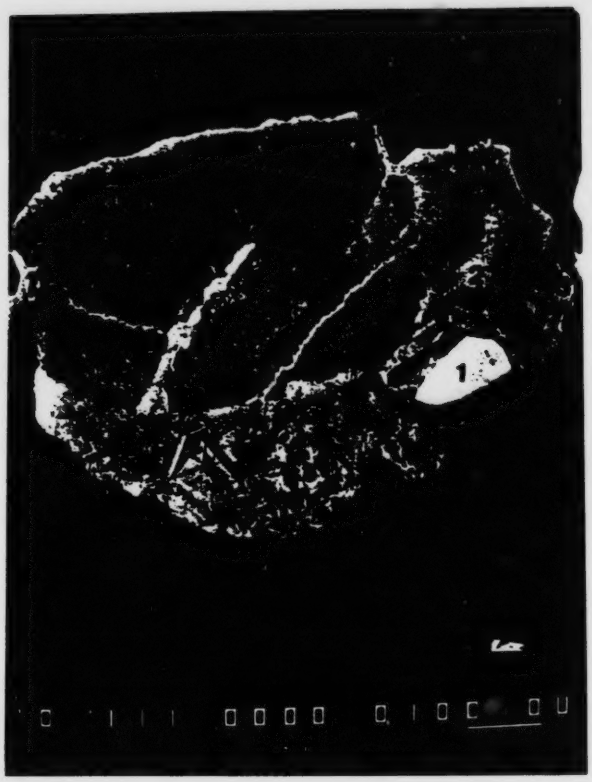


FIGURE 13. Inclusions of hematite (1) in psilomelane (2). Psilomelane grades into crystalline pyrolusite (3). Dark grey (4) is wad.

Backscattered Electron Image
Bar scale = 100 micrometers

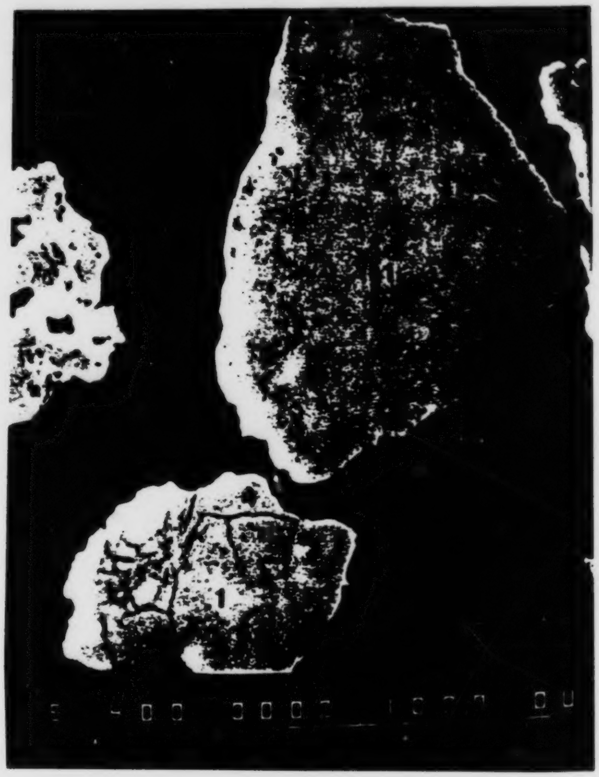


FIGURE 14. Large, +20 mesh in size, free grains of psilomelane (1) in rougher spiral middlings.

Backscattered Electron Image
Bar scale = 1000 micrometers

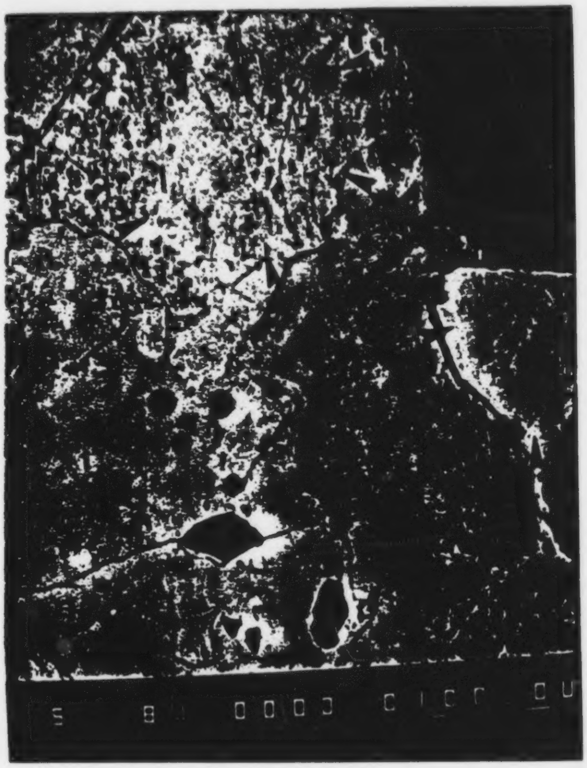


FIGURE 15. Very fine grained psilomelane (within areas marked by arrows) filling pores in net-like textured martite (very light grey). Manganese goethite is marked with (1).

Backscattered Electron Image
Bar Scale = 100 micrometers

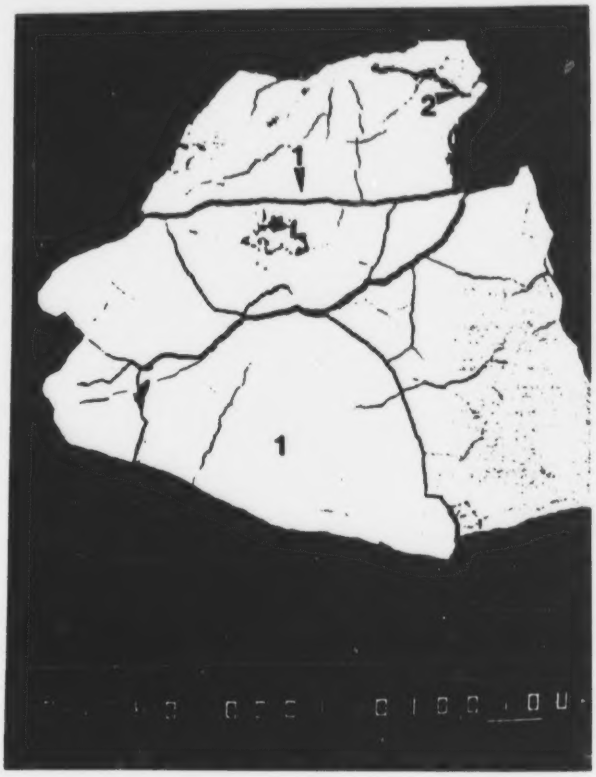


FIGURE 16. Free grain of psilomelane (1) cut by veinlets of barium-rich psilomelane (light grey, arrowed 1) and wad (dark grey, arrowed 2).

Backscattered Electron Image
Bar Scale = 10 micrometers

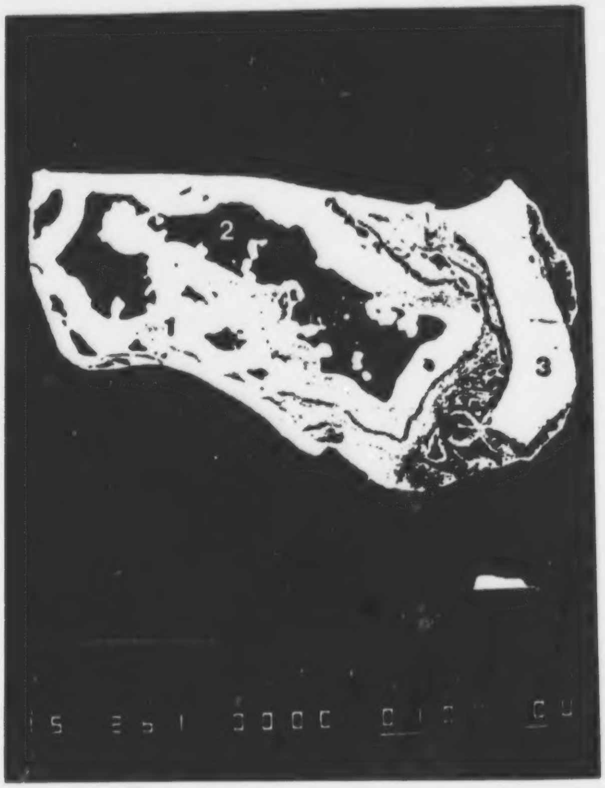


FIGURE 17. Colloform psilomelane (1) composed of bands containing uneven amounts of manganese in association with quartz (2) and hematite (3).

Backscattered Electron Image
Bar scale = 100 micrometers

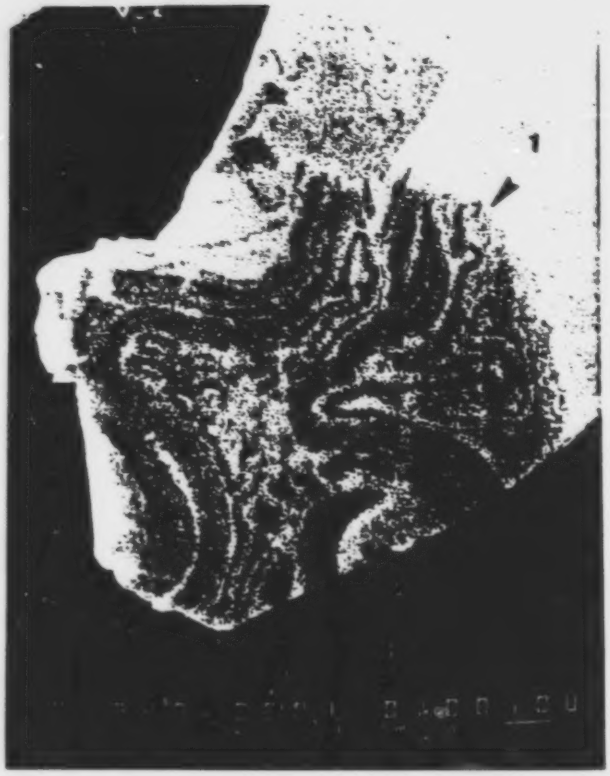


FIGURE 18. Psilomelane (1) replacing goethite (lighter bands) and limonite (darker bands). The replacement front (arrowed) is oblique to the banding.

Backscattered Electron Image
Bar Scale = 100 micrometers

4.3.3 Goethite Rich in Manganese

Goethite containing more than 5.0% manganese was identified as a manganese mineral.

Several grains of goethite in which the concentration of manganese ranged from 20.0% to 27.0% were also observed.

Manganese goethite is always microcrystalline and occurs as patches and veinlets in goethite free of manganese (Figure 19).

Fine patches and streaks of manganese goethite occur also in composite particles with hematite replaced to some extent by goethite free of manganese (Figure 20) and as pore filling material in the manganese-rich grains of martite.

4.4 Goethite Free of Manganese

The phase consists of goethite with no more than 5.0% of manganese, and limonite which appears to be virtually free of manganese. Microprobe analysis of the minerals comprising the phase has shown that the iron content in goethite ranges from 50.0% to 57.0% while limonites carry from 25.0% to 45.0% iron. A density of 4.28 and an average content of iron 46.0% have been assumed for the phase.

Goethite free of manganese and limonite remain in a close relation to each other since most of the limonites seem to be formed as a result of alteration of goethite (Figure 21). Patches and streaks of limonite are almost invariably present in the grains of goethite free of manganese and in the manganese-rich goethite.

Goethite free of manganese, referred to as "goethite" is a secondary mineral after hematite and magnetite, but it may also accumulate in fractures and voids. As a result, the mineral tends to form either very fine intergrowths with hematite, magnetite and manganese minerals (Figure 22) or coarse accumulations that are a source of large, often free grains in the +20 mesh fractions of the samples (Figure 23).

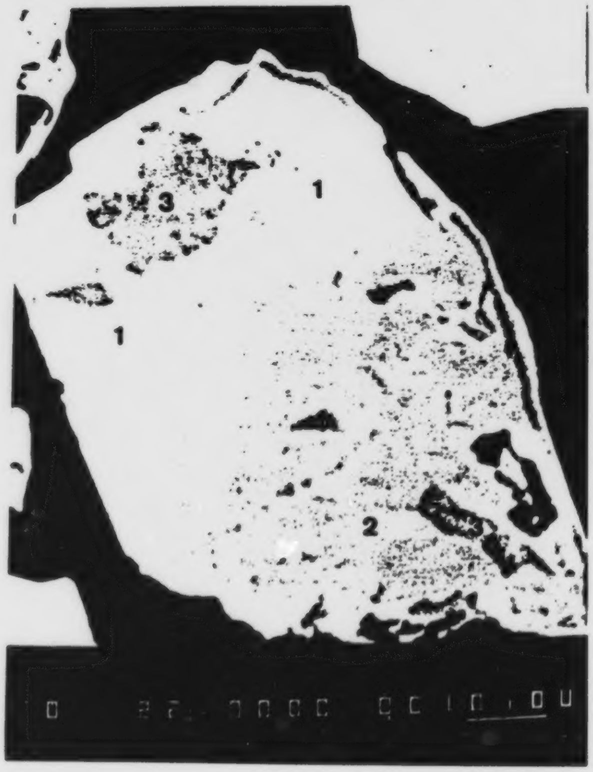


FIGURE 19. Manganese goethite (1) intergrown with manganese-free goethite (2) and limonite (3).

Backscattered Electron Image
Bar Scale = 10 micrometers

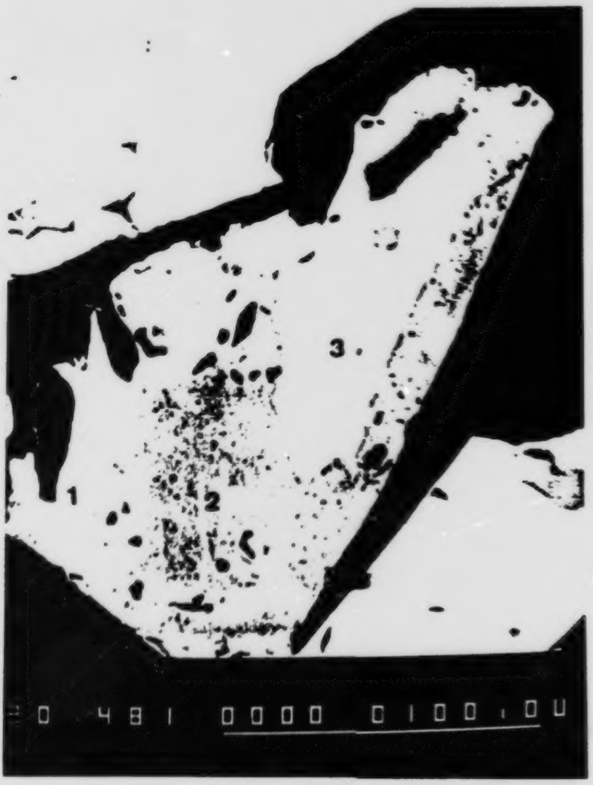


FIGURE 20. Manganese goethite (1) grading into low manganese goethite (2) in particle containing hematite (3) and quartz (4).

Backscattered Electron Image
Bar Scale = 100 micrometers

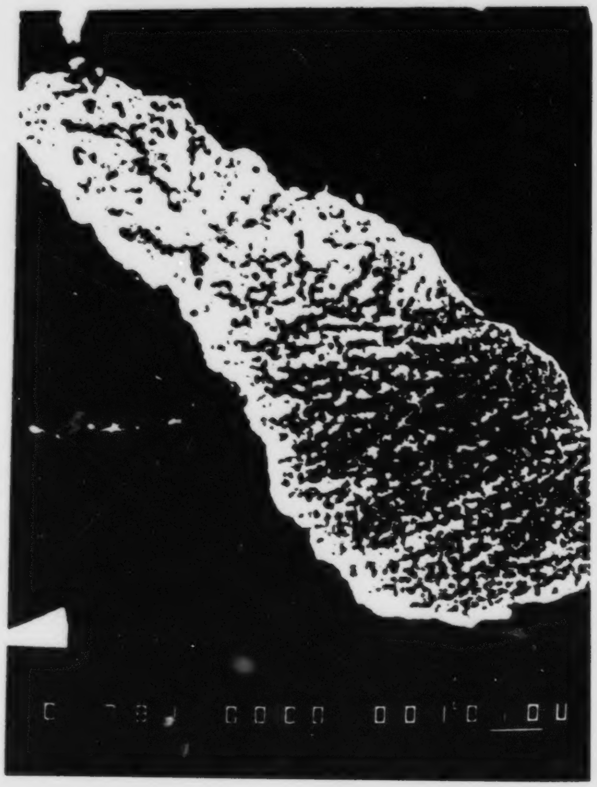


FIGURE 21. Goethite (1) replaced by limonite (2).

Backscattered Electron Image
Bar Scale = 10 micrometers

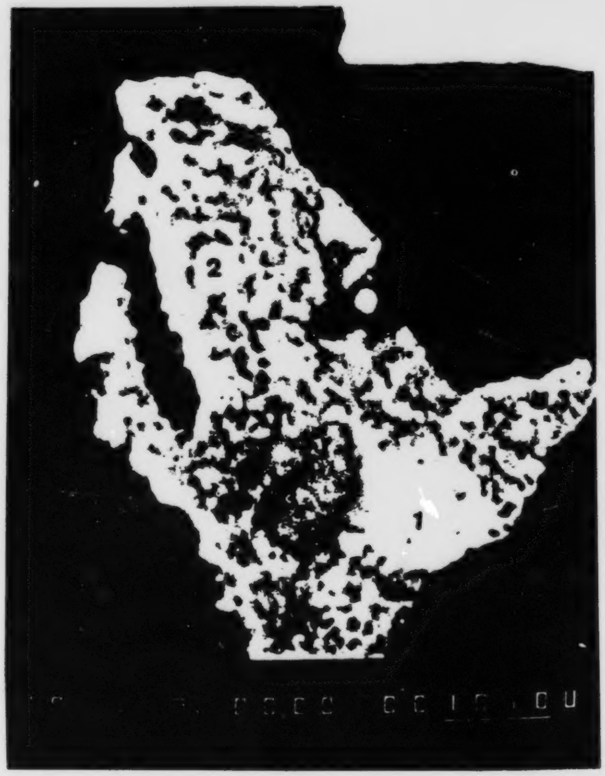


FIGURE 22. Fine intergrowths of hematite (brightest, 1), goethite (grey, 2), limonite (dark grey, 3) and quartz (4).

Backscattered Electron Image
Bar Scale = 10 micrometers

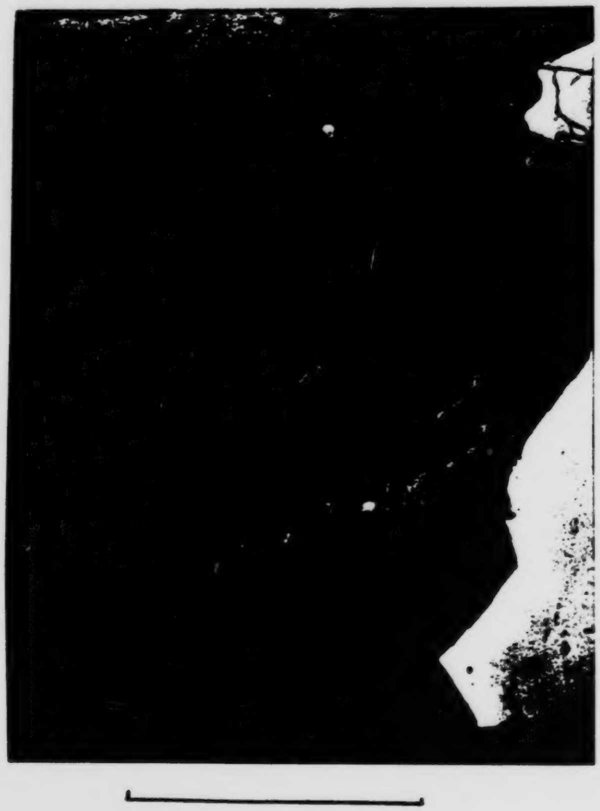


FIGURE 23. Free grain of colloform goethite (1).

Optical Microscope
Bar Scale = 0.8 mm

Replacement of martite by goethite (Figure 24) leads to the formation of very complex textures from which liberation of individual minerals is very difficult, unless overgrinding (to minus 400 mesh) is considered.

Goethite replaces aggregates of hematite along the grain boundaries (Figure 25). Upon communition of such aggregates, the goethite tends to remain attached to the grains of hematite (Figure 26) even in the minus 200 fraction mesh of the mill products.

Quartz/goethite/other oxides parageneses were observed mainly in the ore particles characterized by brecciated textures (Figure 27) in which the grain size of minerals ranges from a few microns to tens of microns.

4.5 Silicates

4.5.1 Quartz

Quartz with the density of 2.6 and 46.0% silica is the major component of this phase.

Most of the unliberated quartz is combined with hematite in granular aggregates (Figure 28) from which it is easily liberated due to weak bonding between the minerals.

The liberation of quartz is very high in each sample examined due to its grain size, the maximum size being 182.0 micrometers.

Quartz occurs also as blebby inclusions in hematite (Figure 29). The inclusions are usually very small and range from 1 to 10 micrometers (Figure 29). They cannot be liberated from the hematite grains, unless overgrinding is applied.

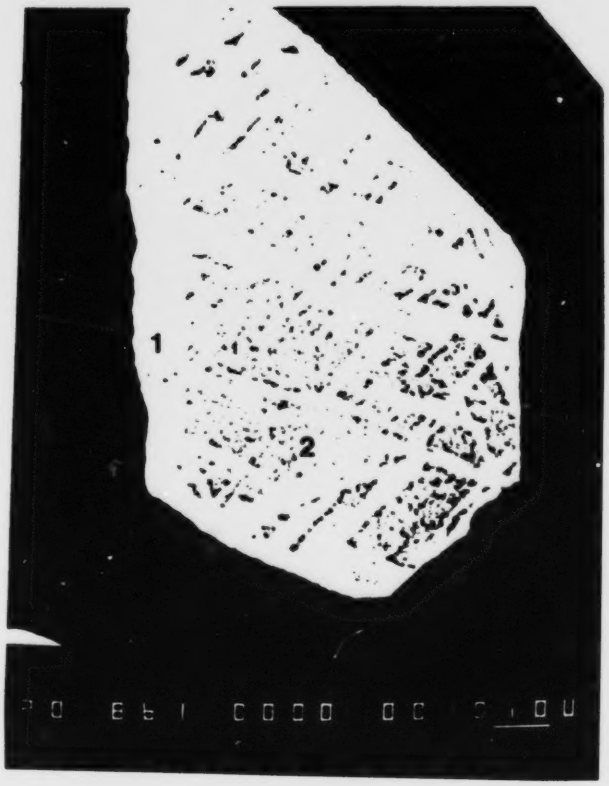


FIGURE 24. Replacement of martite (1) by goethite(2).

Backscattered Electron Image
Bar Scale = 10 micrometers

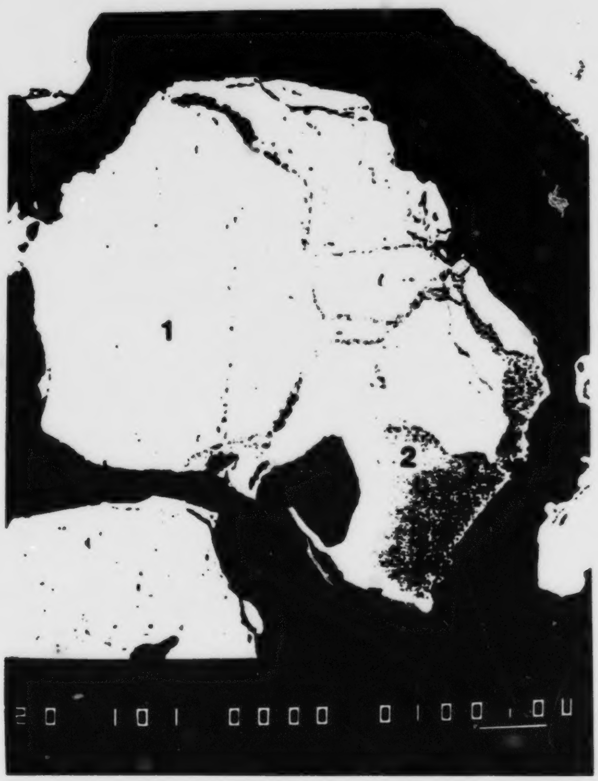


FIGURE 25. Aggregate of hematite (1) replaced along interstitial planes by goethite (2).

Backscattered Electron Image
Bar Scale = 10 micrometers

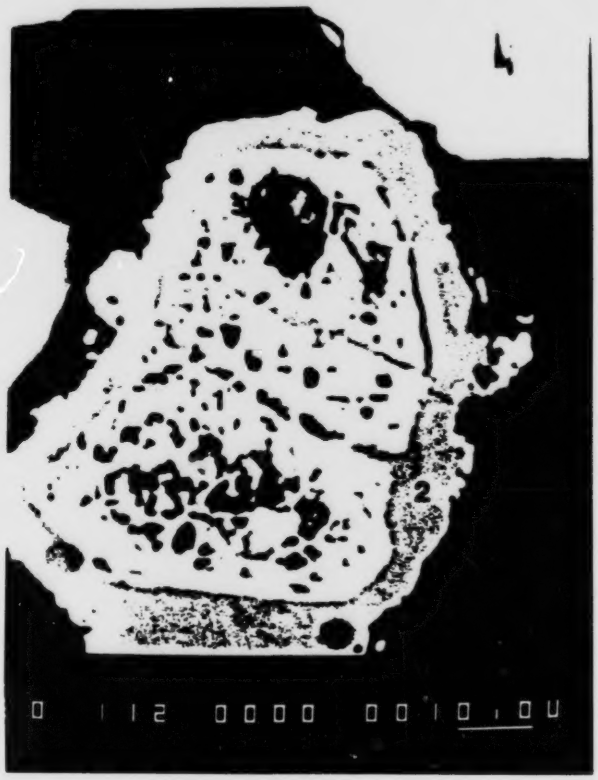


FIGURE 26. Grain of martite (1) with a thin film of goethite (2) in fraction minus 200 mesh. Quartz is marked with (4).

Backscattered Electron Image
Bar scale = 10 micrometers

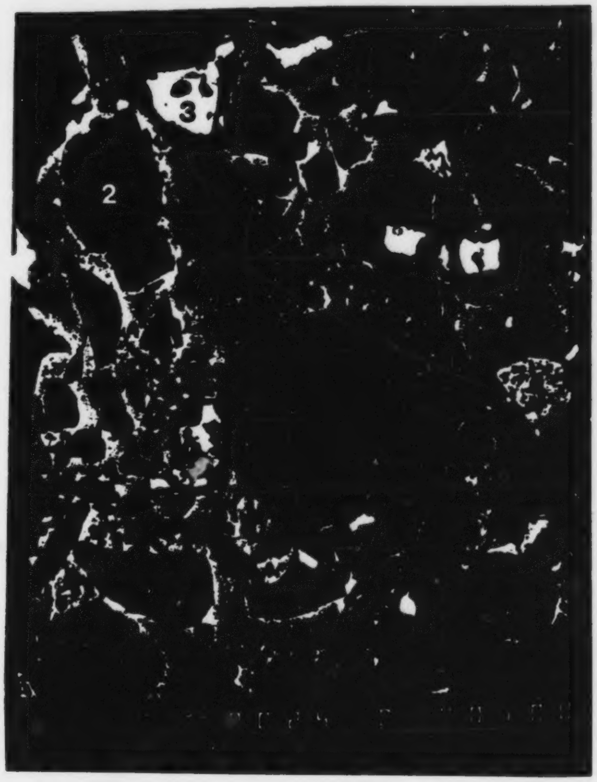


FIGURE 27. Brecciated texture. Goethite (1) is intergrown with quartz (2), hematite (3) and martite (4). Fragment of composite particle.

Backscattered Electron Image
Bar scale = 10 micrometers

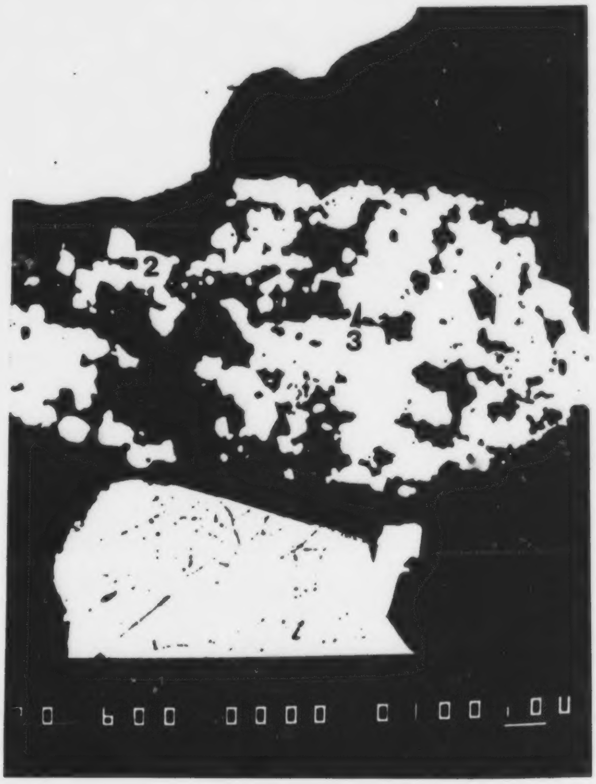


FIGURE 28. Granular aggregate of quartz (1), hematite (2), goethite (3). Note fine inclusions of quartz in hematite (arrowed).

Backscattered Electron Image
Bar scale = 10 micrometers

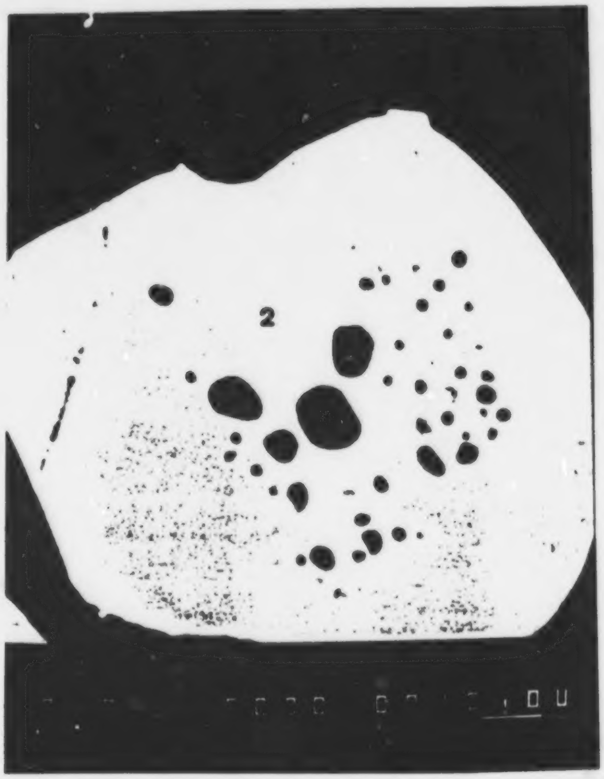


FIGURE 29. Inclusions of quartz (1) in hematite (2).

Backscattered Electron Image
Bar scale = 10 micrometers

4.5.2 Other Silicates

Trace amounts of garnet, amphibole, chlorite and an unidentified manganese silicate were observed in the samples. No detailed work has been done on these minerals due to their low concentrations.

4.6 Other Mineral Phases

Trace amounts of iron carbonates were observed. It was visually estimated that the samples from the ORF test were slightly richer in carbonates than the samples from the Scully Concentrator. The image analysis program classified and measured the carbonate grains as goethite free of manganese.

5.0 MINERAL BALANCE CALCULATIONS

The MATBAL computer program which is part of the Simulated Processing of Ore and Coal (SPOC) was used to calculate mineral balance for the spiral plant of the Scully Concentrator.

Data for the calculations were provided by the mineralogical examination and chemical assays of the mill products.

The flowsheet used for the calculations consisted of three nodes - Rougher Spirals, Cleaner Spirals and Middling Cyclones, and eight streams connected to the nodes. Below is the list of the streams:

1. Sizing Screen Undersize
2. Rougher Spiral Middlings
3. Rougher Spiral Tailings
4. Rougher Spiral Concentrate
5. Cleaner Spiral Tailings
6. Cleaner Spiral Concentrate
7. Middlings Cyclone Underflow
8. Middlings Cyclone Overflow

Data for the Trommel Screen Undersize and the Sizing Screen Oversize were not included in the balance calculations because no concentration occurs at the sizing screen.

Mineralogical data were not available for the Middlings Cyclone products. Data for the equivalent streams were calculated using the chemical assays obtained at RPC. It was assumed that the hematite plus magnetite and goethite phases followed the same ratio as Fe_2O_3 in these two product streams and that the manganese minerals and silicates were divided between each product stream in the same ratio as the MnO and SiO_2 respectively.

The flow rate of the Sizing Screen Undersize was designated as 100%. The flow rates of the Rougher Spiral Middlings, the Cleaner Overflow were specified based on information from Wabush Mines and the calculations using the chemical assays.

The results of the calculations are reported in Appendices K-1 and K-2. Refer also to Chapter 6.6.

Below is the flowsheet used for the calculations. Complete flowsheet of the concentrator is to be found in Appendix N.

6.0 RESULTS

6.1 Sieve Analysis

The sieve analyses of the samples from the Scully Concentrator are reported in Appendix A-1.

Appendix A-2 reports the sieve analysis data for the samples from the ORF bench test.

6.2 Chemical Assays of the Samples

The samples from the Scully Concentrator were assayed at RPC. The results are presented in Appendix B-1.

The analyses of iron, manganese and silicon determined at RPC for the Scully Concentrator samples correspond closely to the equivalent values reported by Wabush Mines.

The iron and manganese analyses reported by ORF for the bench test samples were used for the mineral quantities calculations. The analyses are reported in Appendix B-2.

6.3 Grain Size of the Mineral Phases

The data on the grain size of the mineral phases in the samples of the mill products are reported in Appendices C, D, E.

The data on the products from the Scully Concentrator are included in the Appendices C-1 to C-4. Appendices D-1 to D-4 contain the data on the bench test products from ORF.

Appendices C and D report the data in the form of the graphs. Appendix E contains the data compiled in tables.

The graphs summarize the data on the grain size distribution generated by the AIA analysis of individual sieve fractions of the products. Therefore, they represent combined (whole) products. Separate graphs have been produced for each of the four mineral phases and each mill product examined.

Quantities of the free and locked grains in each size class (see also Chapter 3.4.2) are presented in the form of the bars and numbers. Each bar (number) represents a percentage of the total amount (area as measured and weight as assumed) of a mineral in the product. The numbers listed in the graphs total 100%.

The content of locked grains finer than 65 microns (approximately minus 200 mesh) in the combined samples was calculated. The data is reported as a percentage of a total amount of a given mineral in a product in Appendix E-1 (samples from the Scully Concentrator) and E-2 (samples from ORF).

6.4 Liberation of the Mineral Phases

The classification of the ore particles based on the area percent occupied by the mineral phases that form those particles has been performed (see also Chapter 3.4.3).

Appendix F provides a quick insight into what percentage of a total amount of each mineral phase in the combined products is present in each of the eleven classes of liberation. The two right hand bars in the graphs (classes of liberation 85 and 95) show the percentage of a total amount of a mineral phase occurs as free grains in a particular mill product. No detailed work has been done on the middling particles (classes of liberation 0 to 85), but the graphs provide basic information on the distribution of the mineral phases in such particles.

The graphs included in Appendix F were produced from numerical data (generated by the study) and presented to Wabush Mines Ltd.

The results of the detailed analysis of the distribution free mineral grains are included in Appendices C, D, G and H.

The data on the sampled products from the Scully Concentrator are presented in the form of tables and graphs in Appendices G-1 to G-3. Appendices H-1 to H-3 report equivalent data on the samples from ORF.

The tables in the Appendices G-1 and H-1 report quantities of the free grains of the mineral phases in the individual sieve fractions of each mill product. The quantities of the free grains are reported as a percentage of a total amount of a given mineral phase in each sieve fraction of the products.

The data on the Cleaner Spiral Concentrate are presented in the separate table due to the number of sieve fractions examined in this sample.

The graphs presented in Appendices G-2 and H-2 illustrate the increase in the accumulated (starting from coarsest sieve fraction) weight of the free mineral grains of each mineral phase towards the finer fractions of the mill products. The data points represent sieve fractions of the products. The values indicate the cumulative weight percent of free mineral grains in the mill products. The maximum value for a particular mineral is equivalent to the total weight percent of free grains in the product. Note that no interpretation (extrapolation, interpolation) of the data illustrated by the curves has been performed.

The tables included in Appendices G-3 and H-3 present the data on the liberation of the mineral components of the products from the Scully Concentrator and the ORF test. These tables show the quantities of the free grains of the mineral components of the samples expressed as weight percentages of a total weight of each mineral in the sample.

6.5 Mineral Quantities

Quantities of the mineral phases were measured in each sieve fraction of the sampled products. Details on the method of the mineral weight calculations in the combined samples and individual sieve fractions are to be found in Chapter 3.4.1.

The data is reported in the Appendices I-1 and I-2 for the Scully Concentrator and J-1 and J-2 for the ORF samples.

Appendices I-1 and J-1 report the relative mineral quantities in the combined products reported as weight percentages of those products.

Appendices I-2 and J-2 show the contribution of the mineral phases from the individual sieve fractions of the products to the total mineral weight in the products expressed in percent.

6.6 Mineral Balance

The mineral balance data for the spiral plant of the Scully Concentrator are included in the Appendices K-1 and K-2.

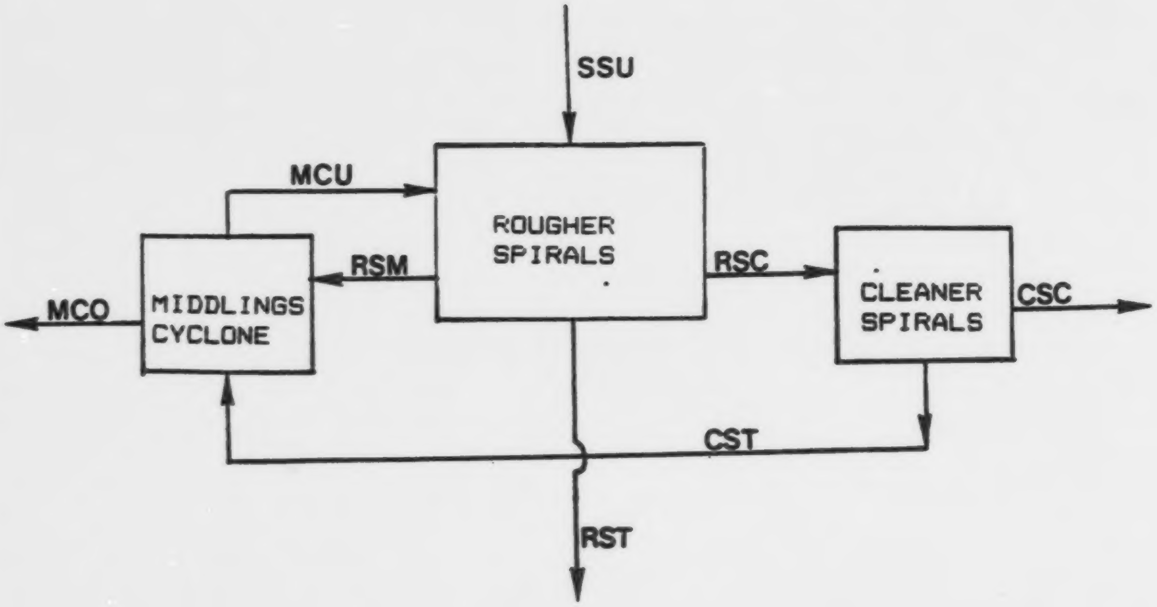
For details on the material balance calculation refer to Chapter 5.0.

The first balance was calculated using the values for both locked and free grains of each mineral phase in each stream. The results are presented in Appendix K-1. The table shows the amounts of each mineral phase in each stream as a percentage of the Sizing Screen Undersize. The mineral amounts do not total 100.0% because the Middlings Cyclone Overflow is recycled to the spirals.

Appendix K-2 contains the results of the mineral balance for the free grains in combined fractions of the samples. The table reports the distribution of free grains for each mineral phase as a percentage of the free grains entering the circuit.

Appendix L reports the results of the balance for the free grains of the mineral phases in individual sieve fractions of the samples. The data on the balance for the locked grains is to be found in Appendix M.

A mineral balance for the ORF bench test has not been done.


SSU
MCU
ROUGHER SPIRALS
RSM
RSC
MCO
MIDDLINGS CYCLONE
CLEANER SPIRALS
CSC
CST
RST

7.0 RESULTS

7.1 Feed to the Spirals of the Scully Concentrator and the Bench Test at ORF.

7.1.1 Hematite combined with magnetite and silicates are the major ore forming minerals and account for 40 wt% to 50 wt% each of the products from the grinding circuit of the Scully Concentrator. Goethite free of manganese and manganese bearing phases are the accessory minerals in these products (Figure 30 and Appendix I-1, Page 175).

7.1.2 The feeds (-28 mesh run and -20 mesh run) to the spirals of the ORF bench test are characterized by a slightly higher content of hematite and magnetite and a lower content of manganese phases (Figure 31 and Appendix J-1, Page 183) than the feed at the Scully Concentrator.

7.1.3 The sample of the trommel screen undersize TSU of the Scully Concentrator is characterized by a fairly "normal" grain size distribution of the hematite combined with magnetite and silicates (Figure 32), with the maximum in the range 109-180 micrometers. Goethite free of manganese and manganese phases have a "bimodal" grain size distribution in this sample, with two peak maxima at 109-180 micrometers and 500-800 micrometers (Figure 33).

7.1.4 The content of locked grains finer than 65 microns, measured as a wt% of a total mineral weight in the samples of the grinding unit of the Scully Concentrator and the mill products of the ORF bench test, is higher for the manganese minerals and the manganese free goethite than for the hematite combined with magnetite and silicates (see Appendices E-1 and E-2, Pages 138-141).

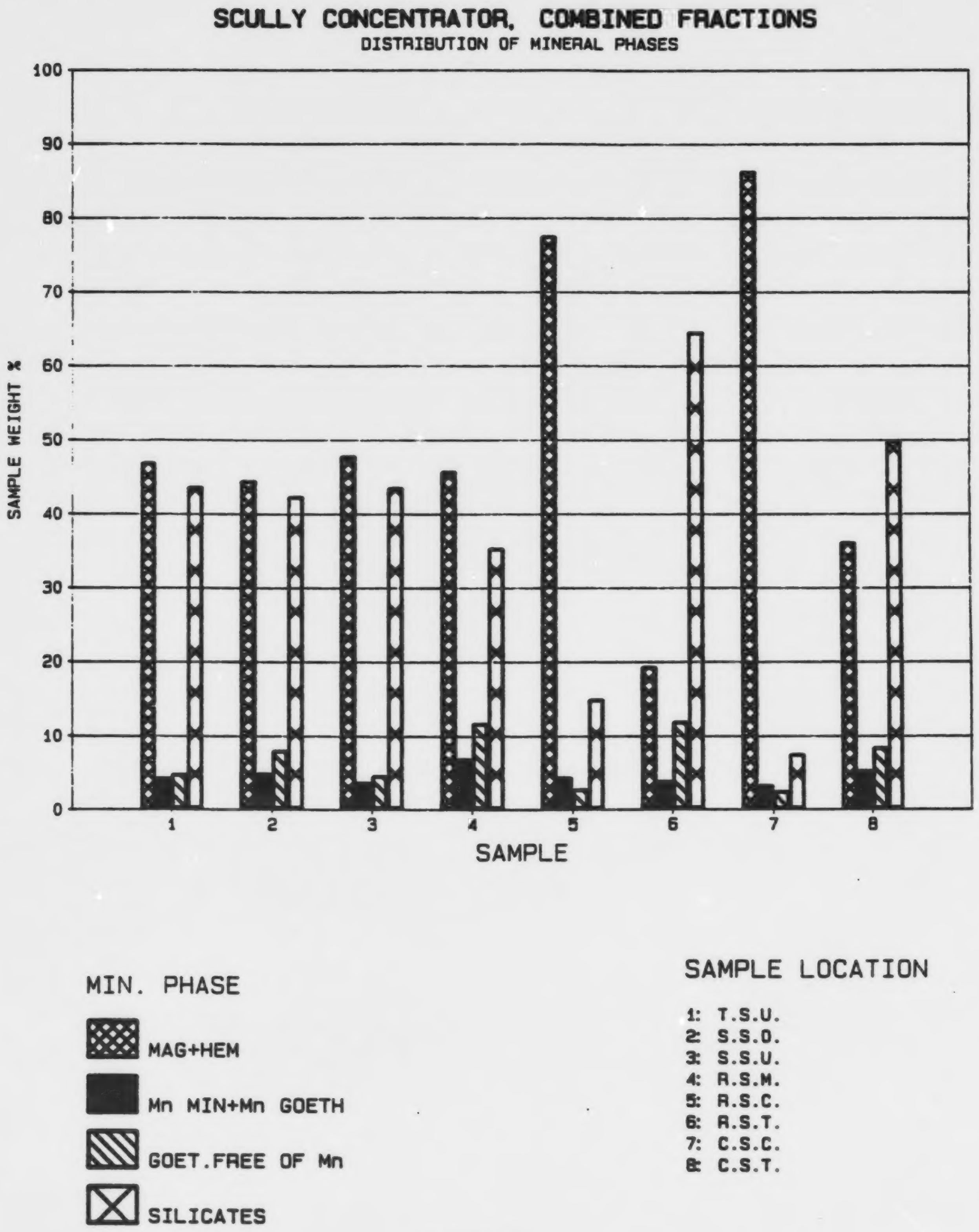

SCULLY CONCENTRATOR, COMBINED FRACTIONS
DISTRIBUTION OF MINERAL PHASES
SAMPLE WEIGHT %
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
SAMPLE
MIN. PHASE
MAG+HEM
Mn MIN+Mn GOETH
GOET.FREE OF Mn
SILICATES
SAMPLE LOCATION
1: T.S.U.
2: S.S.O.
3: S.S.U.
4: R.S.M.
5: R.S.C.
6: R.S.T.
7: C.S.C.
8: C.S.T.

FIGURE 30

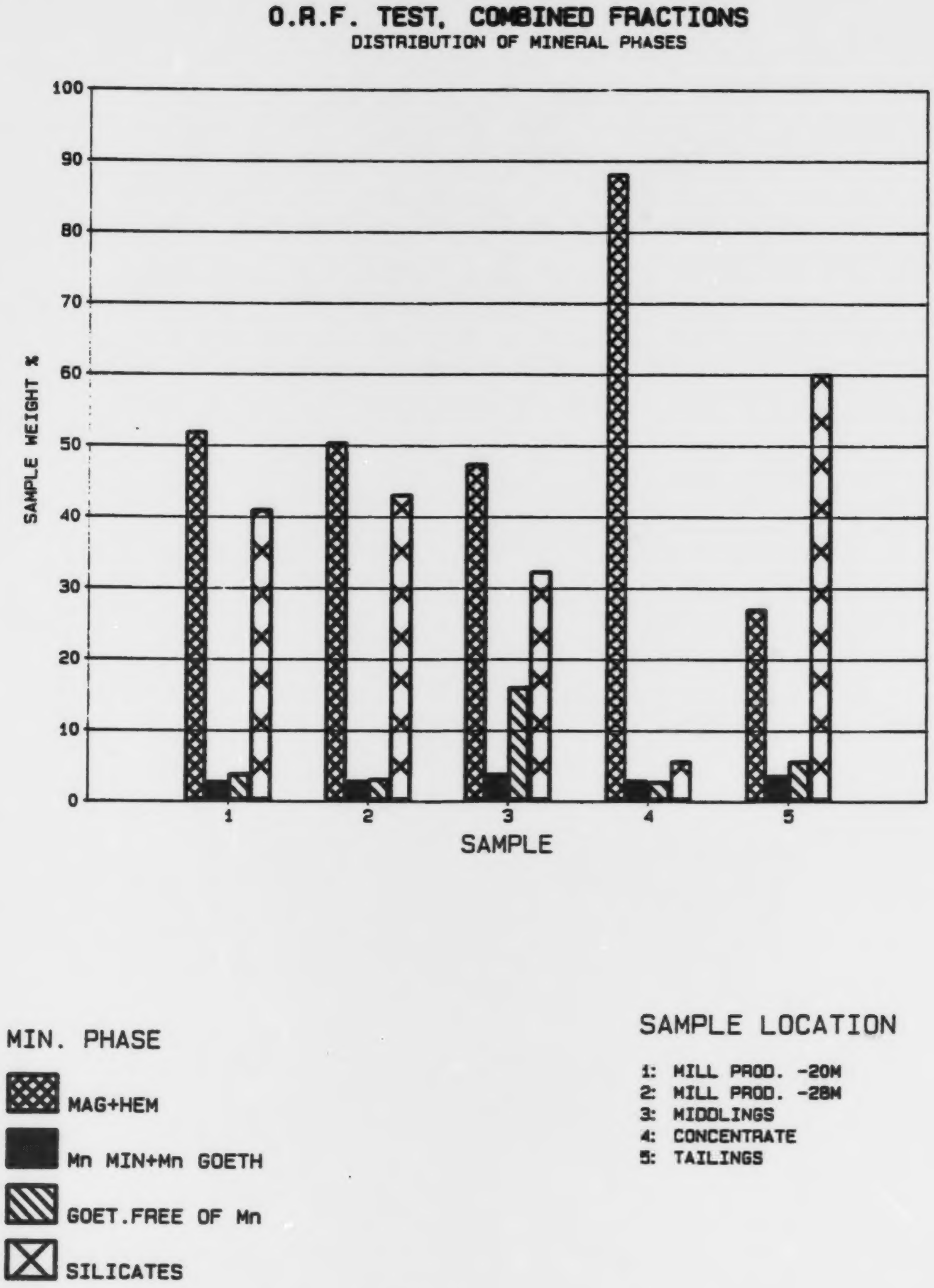

O.R.F. TEST, COMBINED FRACTIONS
DISTRIBUTION OF MINERAL PHASES
SAMPLE WEIGHT %
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
SAMPLE
MIN. PHASE
MAG+HEM
Mn MIN+Mn GOETH
GOET.FREE OF Mn
SILICATES
SAMPLE LOCATION
1: MILL PROD. -20M
2: MILL PROD. -28M
3: MIDDLINGS
4: CONCENTRATE
5: TAILINGS

FIGURE 31

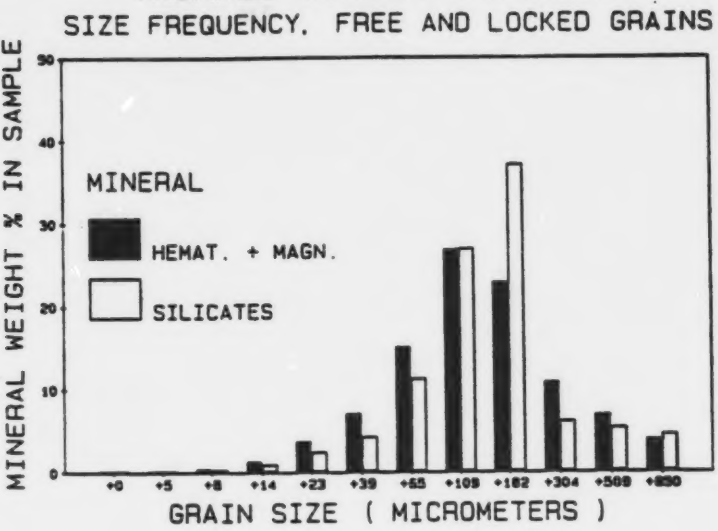


FIGURE 32

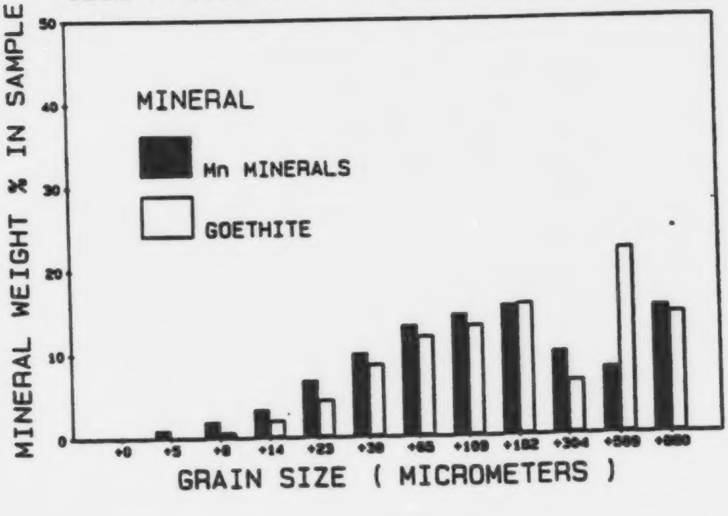


FIGURE 33

7.1.5 The differences in the grain size distribution of the ore forming minerals are reflected in their liberation patterns. Upon comminution of the ore, the silicates and hematite combined with magnetite form relatively more free grains (measured as a percentage of a total mineral weight in the product) than the manganese free goethite and the manganese phases (see Appendices F Page 142, G-3 Page 161 and H-3 Page 172).

7.1.6 For the reasons listed in 7.1.5 the feed to the spirals (SSU) of the Scully Concentrator contains highly liberated hematite combined with magnetite and silicates, while the manganese free goethite and the manganese phases are liberated to a much lower extent ranging 46% - 63% each of their total mineral weight in the sample. This is illustrated in Figure 34. The area below each curve in this figure represents a percentage of a total mineral weight contained in the locked grains in each grain size class.

7.1.7 The finer grind of the ore to -28 mesh applied during the bench test at ORF resulted in a higher overall liberation of the manganese minerals and a lower liberation of the goethite free of manganese, than those recorded from the SSU of the Scully Concentrator where the ore is ground to -20 mesh. The equivalent values for the hematite combined with magnetite and the silicates are also slightly lower for the ORF test. It is believed that erratic distribution of the textures of the accessory minerals in the deposit and their low quantities (non-statistical number of ore particles measured by the AIA program) combined with such factors as a measuring error and sampling procedure, could have influenced the data on the mineral liberation in the products from the plant and the test. The content of locked grains of the hematite combined with magnetite, the goethite free of manganese and the silicates finer than 65 microns is definitely higher in the TSU than in the mill product -20 mesh from the bench test (Appendices E-1 Page 138 and E-2 Page 140), while the equivalent values for

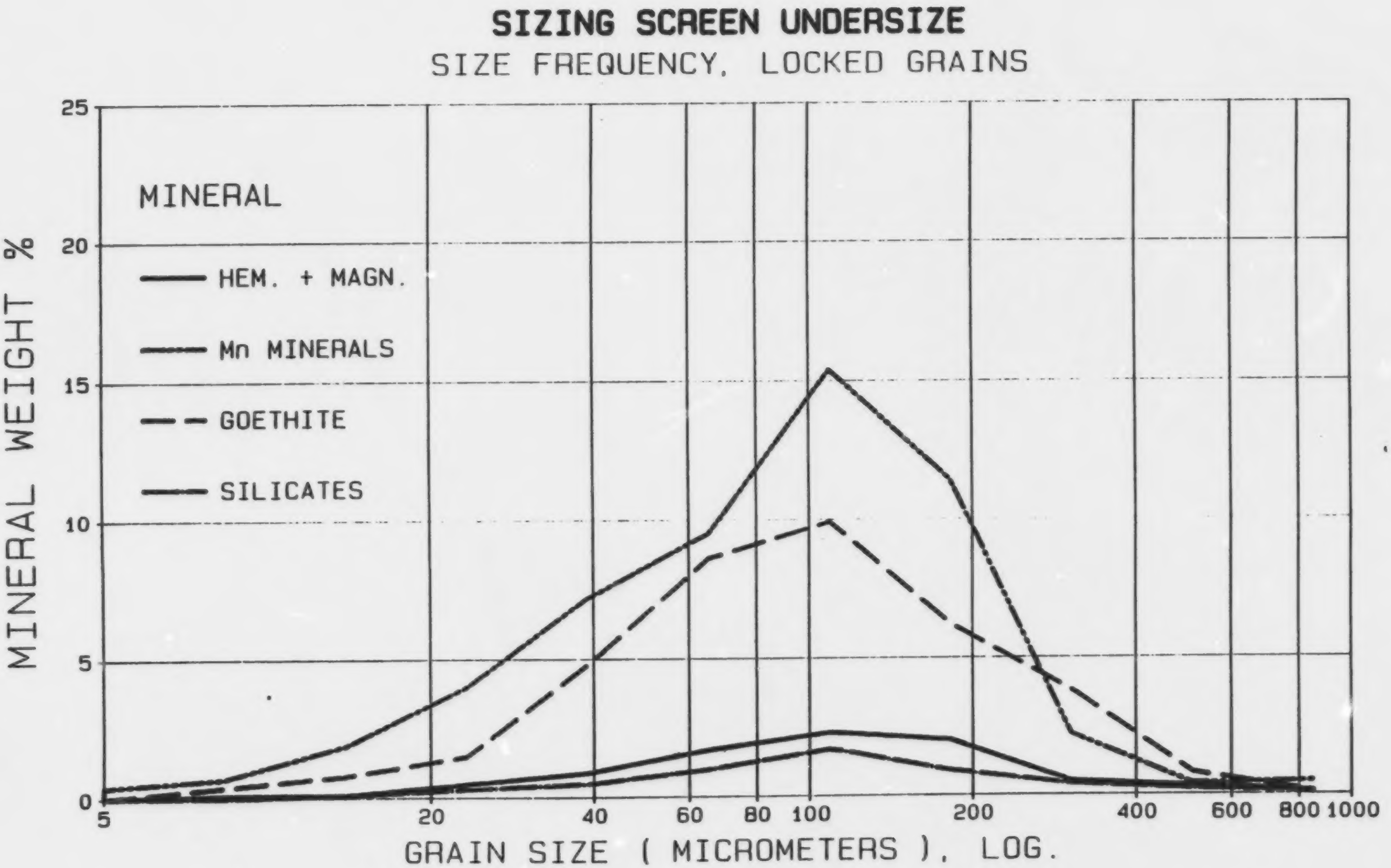

SIZING SCREEN UNDERSIZE
SIZE FREQUENCY, LOCKED GRAINS
MINERAL
HEM. + MAGN.
Mn MINERALS
GOETHITE
SILICATES
MINERAL WEIGHT %
0
5
10
15
20
25
5
20
40
60
80
100
200
400
600
800
1000
GRAIN SIZE (MICROMETERS), LOG.

FIGURE 34

the manganese phases are higher in the TSU than in the mill product -20 mesh. Five sieve fractions of each product from the grinding circuit of the Scully Concentrator and only four sieve fractions from the ORF mill products were examined.

7.1.8 Based on the image analysis data it was calculated that 56.7 wt% of the goethite free of manganese enters the spiral plant of the Scully Concentrator in the particles that contain hematite combined with magnetite. Such particles may or may not contain all the other phases (or phase). The equivalent value for the mill product -28 mesh from the bench test is 52.2 wt%. It was also calculated that 39.4 wt% of the manganese minerals from the SSU of the Scully Concentrator and 54.8 wt% of the mineral from the mill product -28 mesh occur in such particles. Nevertheless, it should be emphasized that these numbers illustrate only a trend characterizing the composition of particles with regard to the manganese minerals/hematite + magnetite/goethite free of manganese parageneses. This is because of an insufficient (non-statistical) number of such particles measured by the AIA program.

7.1.9 Visual estimation of the feed to the spirals from the Scully Concentrator and the ORF bench test indicates that locked grains of the manganese minerals, chiefly those of the manganese rich goethite, are intergrown with the goethite free of manganese. Such composite particles contain frequently hematite, magnetite and martite replaced to a various extent by the Mn-rich and Mn-free goethite (see also Chapter 5.0).

7.1.10 The analysis of the cumulative distribution of the free grains of the mineral phases in the products of the grinding circuits of the Scully Concentrator and the bench test (Appendices G-2 Page 153 and H-2 Page 168) shows, that in order to liberate 80 wt% of the manganese minerals and the goethite free of Mn from any of the reported products, a grind to below 400 mesh (overgrind) should be applied. The overgrind would result in sending more hematite and magnetite to the slime, which, in turn, would increase losses of this phase to the spiral tailings.

7.2 Spiral Circuit of the Scully Concentrator

7.2.1 Upon entering the spirals, the mineral components of the feed, which is blended with the Middlings Cyclone Overflow, are subjected to gravity separation. It was learned from the material balance that in the rougher spirals the middlings constitute 3.6 wt% of the feed, while 46.0 wt% of the feed reports to the tailings and 52.5 wt% of this product reports to the concentrate (Appendix K-1, Page 189).

7.2.2 The middling particles in the rougher spirals contain 3.2 wt% of the hematite combined with magnetite and 3.3 wt% of the silicates from the feed. The equivalent values for the manganese minerals and the manganese free goethite are higher and are 6.4% and 7.4% respectively. This is because of the low liberation of these minerals in the feed and their specific gravity (Appendix K-1, Page 189).

7.2.3 The specific gravity of the manganese minerals and the manganese free goethite cause that the free grains of these phases more readily enter the middlings (a portion of which is returned to the spirals as the Middlings Cyclone Overflow) than the hematite combined with magnetite and the silicates. As shown in Appendix K-2 Page 191, 4.9 wt% of the free grains of the manganese minerals and 6.4 wt% of the liberated goethite free of manganese from the feed report to the middlings. The equivalent values for the hematite combined with magnetite and the silicates are 2.7% and 2.9% respectively.

7.2.4 Results (Appendix K-1, Page 191) show that 17.2 wt% of the hematite and magnetite from the feed reports to the rougher tailings and an additional 6.1 wt% of this phase from the feed is lost to the cleaner tailings.

7.2.5 10.8 wt% of the hematite and magnetite in the rougher tailings and 4.2 wt% of this phase in the cleaner tailings occur as locked grains finer than 65 micrometers (approximately 200 mesh). They occur mainly as blebby inclusions of hematite in quartz. This hematite cannot be recovered without overgrinding the product (Appendices E-1 Page 138 and G-2 Page 153) to minus 400 mesh.

7.2.6 44.3 wt% of the hematite and magnetite in the rougher tailings and 22.9 wt% of this phase in the cleaner tailings occur as free grains in the minus 65 micron fraction (Appendix C-1 Page 78).

7.2.7 83.0 wt% of the free grains of the hematite and magnetite from the feed to the spirals (SSU) reports to the Cleaner Spiral Concentrate (Appendix K-2 Page 192).

7.2.8 45.8 wt% of the manganese minerals and the manganese rich goethite from the feed to the spirals reports to the Cleaner Spiral Concentrate and an equivalent value of 19.4% was recorded for the goethite free of manganese. This is because of the low density of the goethite free of manganese (Appendix K-1 Page 189).

7.2.9 49.5 wt% of the free grains of the manganese minerals from the SSU passes over to the Cleaner Spiral Concentrate (Appendix K-2 Page 192). The visual examination of these grains indicates that they are composed largely of pyrolusite whose density is higher than that of hematite and magnetite. Most of the free grains of the psilomelanes, manganese rich goethite and wad are discarded to the rougher and cleaner tailings.

7.3 Spiral Circuit at ORF

7.3.1 Spiral Circuit product from the -28 mesh feed run was examined, but no mineral balance has been done for the circuit. Nevertheless, it was observed and should be highlighted that:

-the concentrate from the bench test contains more hematite combined with magnetite and less manganese minerals and manganese rich goethite than the concentrate from the Scully Concentrator (compare Appendices I-1 Page 174 and J-1 Page 182).

-the middlings from the ORF test are relatively richer in the hematite and magnetite and contain less manganese minerals than the middlings from the Scully Concentrator (Appendix).

-10.3 wt% of the hematite and magnetite in the tailings is present as locked grains finer than 65 micrometers, while the equivalent value for the CST from the Scully Concentrator is 4.2% (Appendices E-1 Page 138 and E-2 Page 140).

-twice as much manganese minerals and manganese goethite is present in the bench test tailings as locked grains finer than 65 micrometers than in the CST of the Scully Concentrator (Appendices E-1 Page 138 and E-2 Page 140).

-72.1 wt% of the hematite and magnetite in the bench test tailings is liberated as opposed to the 74.6% in the CST of the Scully Concentrator (Appendices G-3 Page 161 and H-3 Page 172).

8.0 CONCLUSIONS

As far as iron recovery and minimizing the manganese content in the spiral concentrates are concerned, the data presented in Chapter 7.0 indicates two major problems of the spiral plant of the Scully Concentrator.

1. Losses of fine hematite and magnetite intergrown with both the silicates and the manganese free goethite as well as losses of free grains of this phase to the spiral tailings

2. High recovery of the manganese minerals in the spiral concentrates which is caused by:

   -high density of pyrolusite and certain (barium rich) psilomelanes that occur as free grains in this product

   -intergrowths of the manganese minerals with hematite and magnetite (e.g. manganese rich goethite replacing martite in very fine intergrowths)

   -the presence of manganese in solid solution with iron in magnetite and martite.

Based on the data generated by the AIA program and mineralogical study of the sampled products, the following suggestions are made:

(i) Any attempt to liberate more manganese minerals in order to separate them from the iron oxides in any mill product would have to be done by overgrinding that product to minus 400 mesh.

(ii) Overgrind as well as any finer grind of the feed to the spirals would send more iron to the tailings

(iii) The ability of the manganese minerals to form middling particles should be utilized in order to concentrate them in this product from which they could be separated by further processing. The spiral middlings at the Scully Concentrator constitute only 3.2 wt% the feed to the spirals. The amount of middlings may be increased either by coarsening of the feed to the spirals or by widening the middling gates at the spiral plant, which would also prevent more iron from entering the tailings.

(iv) Free grains of the manganese minerals of high density will always tend to concentrate with hematite and magnetite in the spirals.

APPENDICES

APPENDIX A-1

Scully Concentrator
Sieve Analysis
All Samples

SIEVE ANALYSIS
Scully Concentrator
All Samples

Sample Mesh	Sieve Fraction (wt%) +20	+35	+65	+150	+270	-270	+400	-400	Total
Micron	+850	+425	+212	+106	+53	-53	+38	-38	%
1. Trommel Screen Undersize	13.2	0.0	45.6	25.4	10.8	5.0	0.0	0.0	100
2. Sizing Screen Oversize	38.9	0.0	41.8	10.1	6.5	2.7	0.0	0.0	100
3. Sizing Screen Undersize	2.4	0.0	50.2	29.4	12.1	5.9	0.0	0.0	100
4. Rougher Spiral Middlings	8.9	0.0	50.0	29.0	10.2	1.9	0.0	0.0	100
5. Rougher Spiral Concentrate	5.2	0.0	47.9	34.3	10.9	1.7	0.0	0.0	100
6. Rougher Spiral Tailings	3.0	0.0	46.2	26.4	16.5	7.9	0.0	0.0	100
7. Cleaner Spiral Concentrate	3.1	14.8	37.1	35.6	9.1	0.0	0.3	0.1	100
8. Cleaner Spiral Tailings	12.8	0.0	35.4	28.3	16.9	6.6	0.0	0.0	100

APPENDIX A-2

ORF Test
Sieve Analysis
All Samples

SIEVE ANALYSIS*

Samples from Ontario Research Foundation

	Sample		Sieve Fraction (wt%)				
		Mesh	+65	+150	+270	-270	Total
		Micron	+212	+106	+53	-53	%
1.	Mill Product, -20M		62.4	22.5	9.5	5.6	100
2.	Mill Product, -28M		48.3	32.7	12.1	6.9	100
3.	Middlings		40.9	43.0	11.6	4.5	100
4.	Spiral Concentrate		46.6	37.2	12.9	3.3	100
5.	Spiral Tailings		59.2	20.8	7.9	12.1	100

*Analysis performed at ORF

APPENDIX B-1

Scully Concentrator
Iron, Manganese and Silicon Analyses
All Samples

Scully Concentrates

Distribution of Major Elements in the Mill Products

Product	Element (wt %)		
	Fe	Mn	Si
TSU	34.1	1.9	19.2
SSO	34.8	2.1	20.0
SSU	35.3	1.7	20.1
RSM	36.9	3.0	16.9
RSC	53.3	1.8	6.9
RST	20.7	1.7	30.6
CSC	59.6	1.4	3.5
CST	28.5	2.5	23.6

APPENDIX B-2

ORF Test, Iron and Manganese Analyses of Samples

ORF Test

Distribution of Major Elements in the Mill Products

Product	Element (wt %)	
	Fe	Mn
Mill Product -20M	37.5	1.6
Mill Product -28M	36.2	1.5
Middlings	40.9	2.1
Concentrate	62.9	1.6
Tailings	23.7	2.2

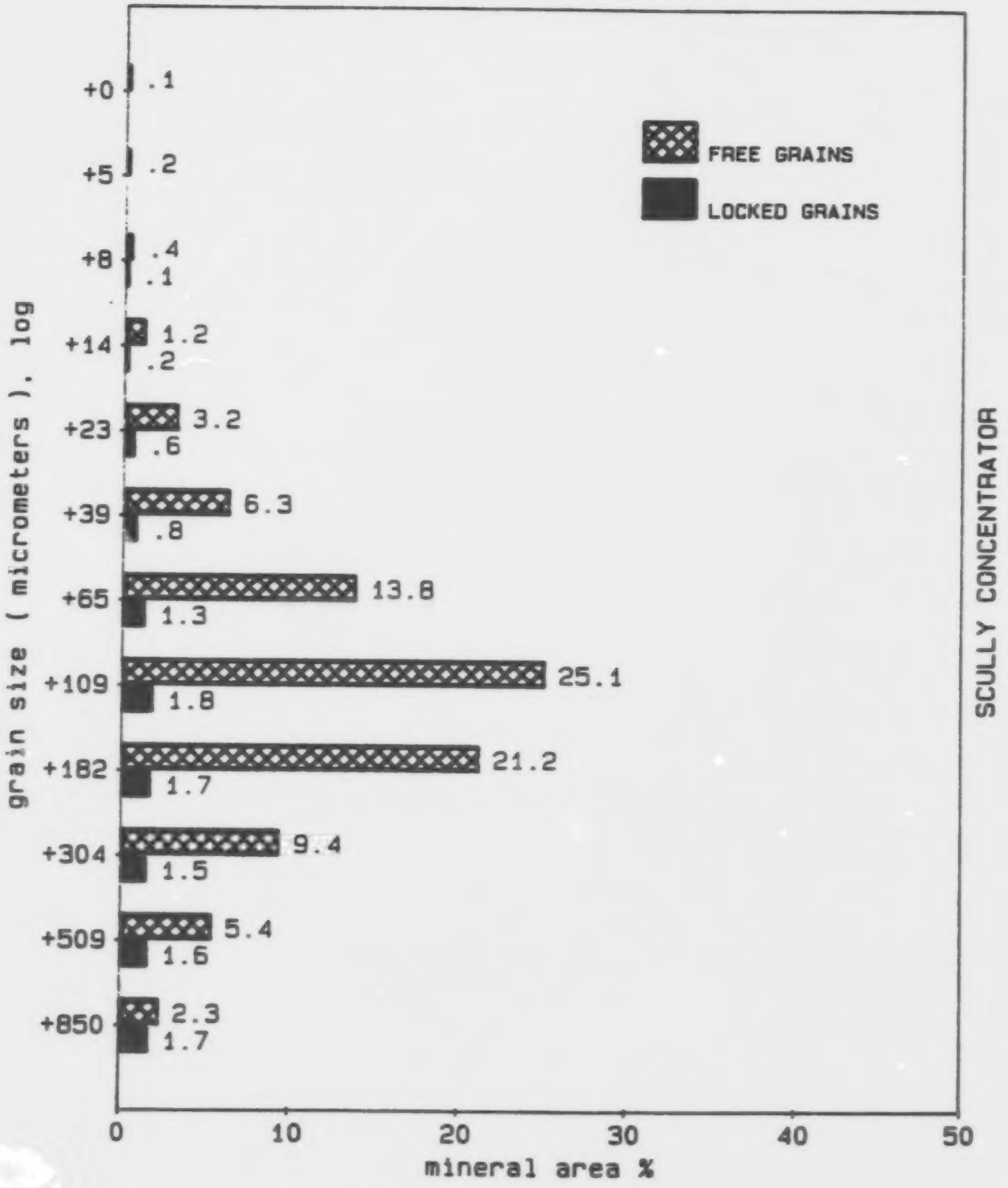
Note: No assay for Si was reported. Content of quartz (silicates) in product was calculated by difference.

APPENDIX C-1

Scully Concentrator
Hematite and Magnetite
Grain Size Distribution,
Combined Fractions.

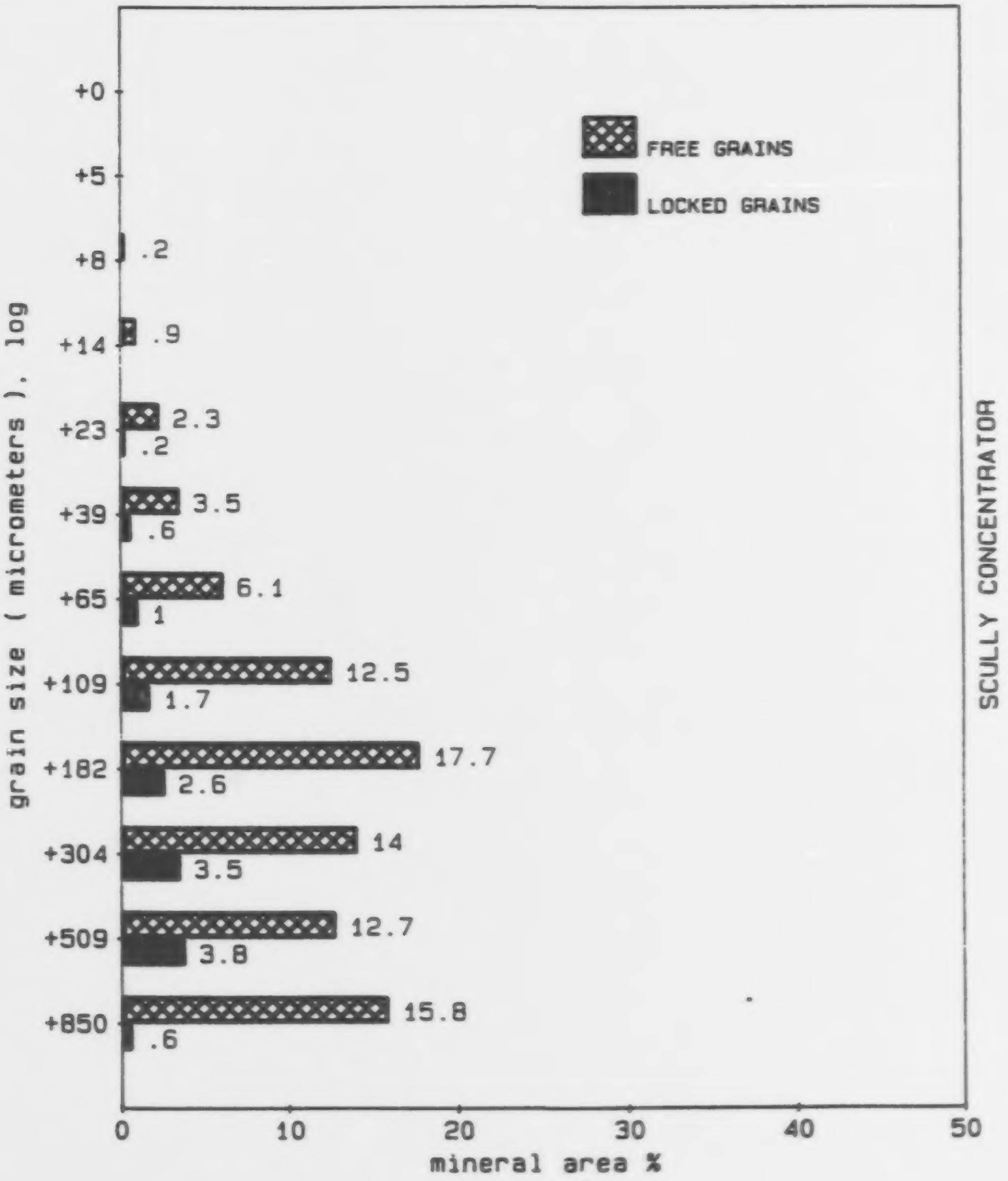
TSU
SSO
SSU
RSM
RSC
RST
CSC
CST

T.S.U. COMBINED FRACTIONS
HEMATITE AND MAGNETITE
SIZE OF FREE AND LOCKED GRAINS



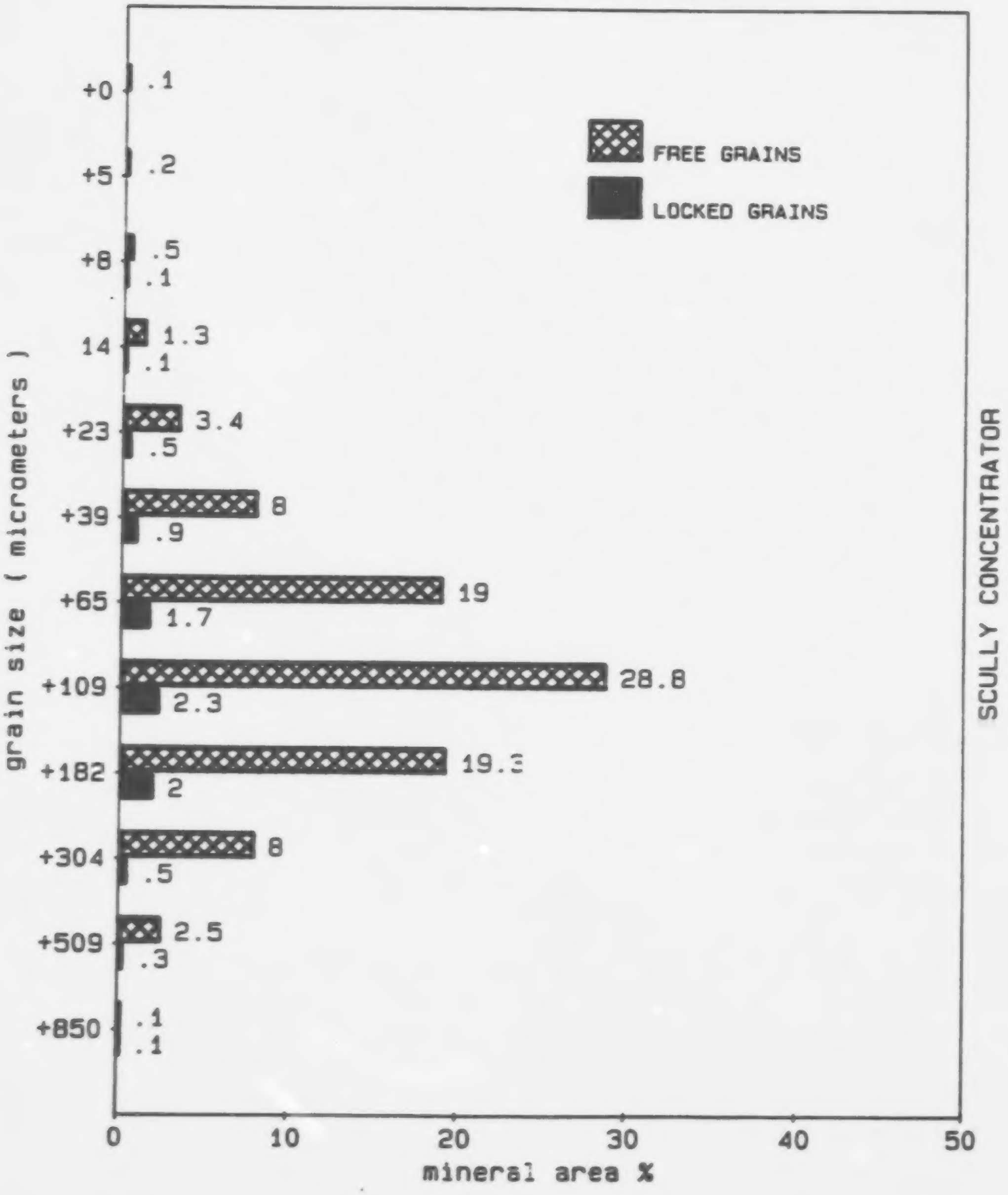
S.S.O. COMBINED FRACTIONS

HEMATITE AND MAGNETITE
SIZE OF FREE AND LOCKED GRAINS



S.S.U. COMBINED FRACTIONS

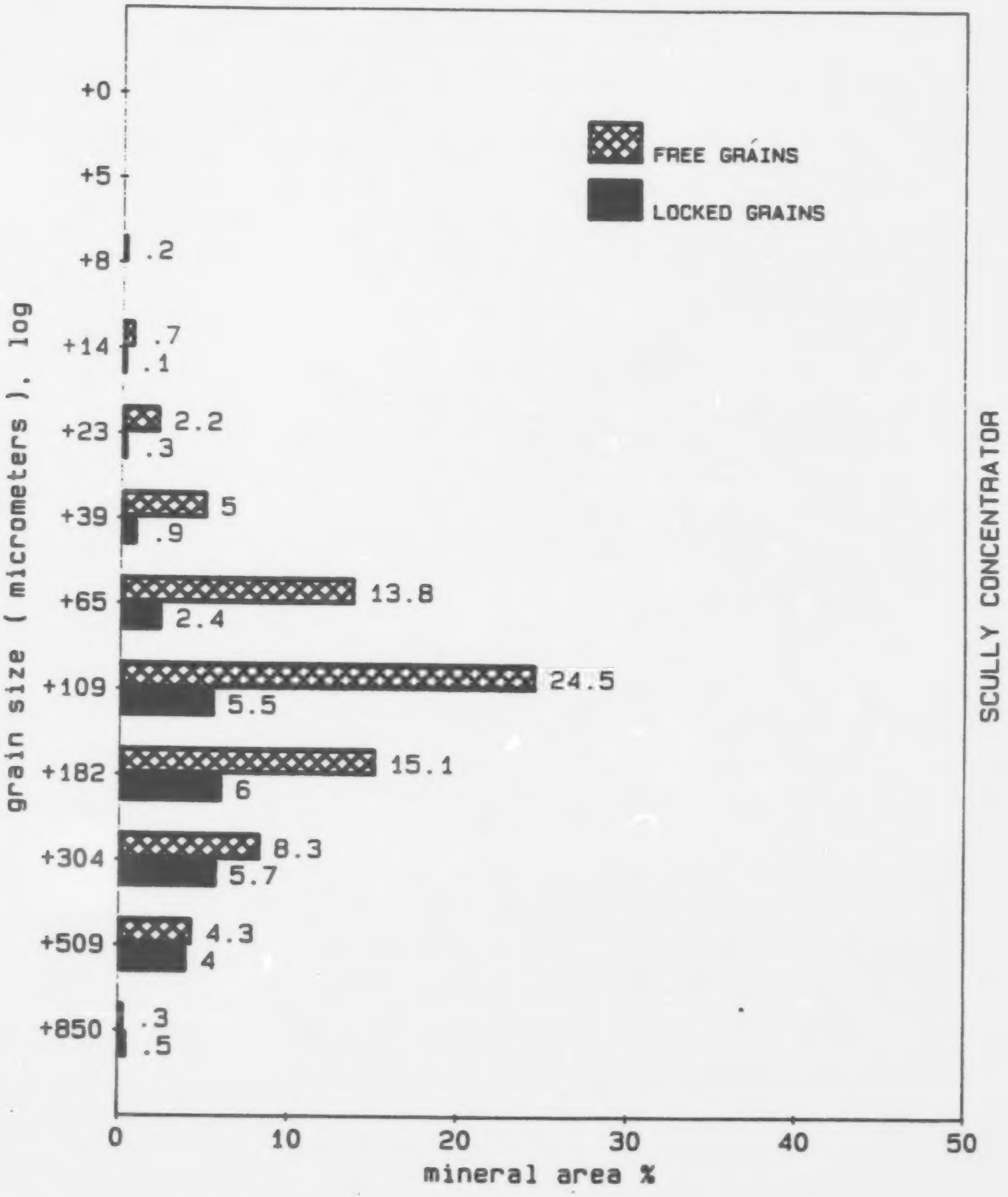
HEMATITE AND MAGNETITE
SIZE OF FREE AND LOCKED GRAINS



R.S.M. COMBINED FRACTIONS

HEMATITE AND MAGNETITE

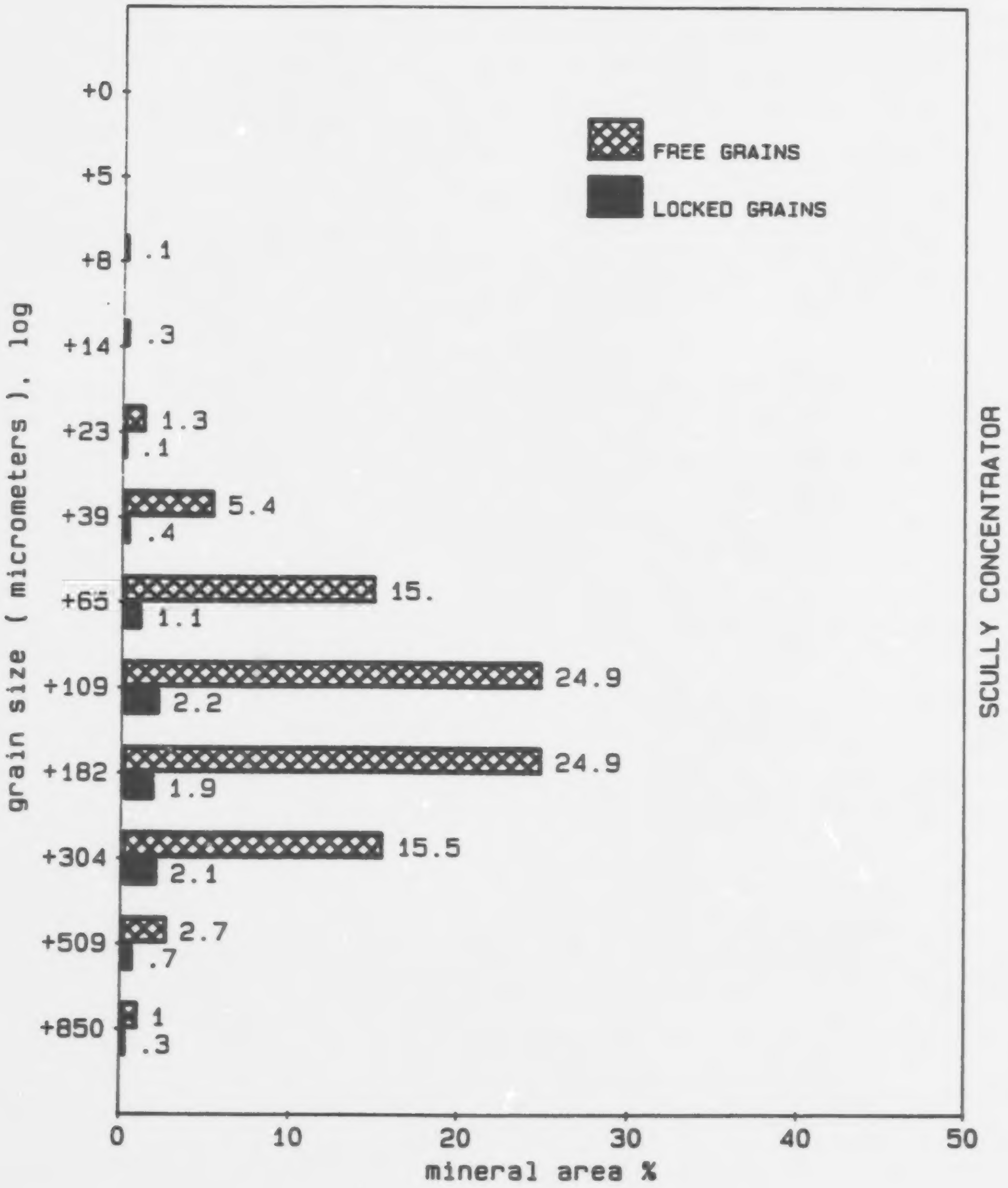
SIZE OF FREE AND LOCKED GRAINS



R.S.C. COMBINED FRACTIONS

HEMATITE AND MAGNETITE

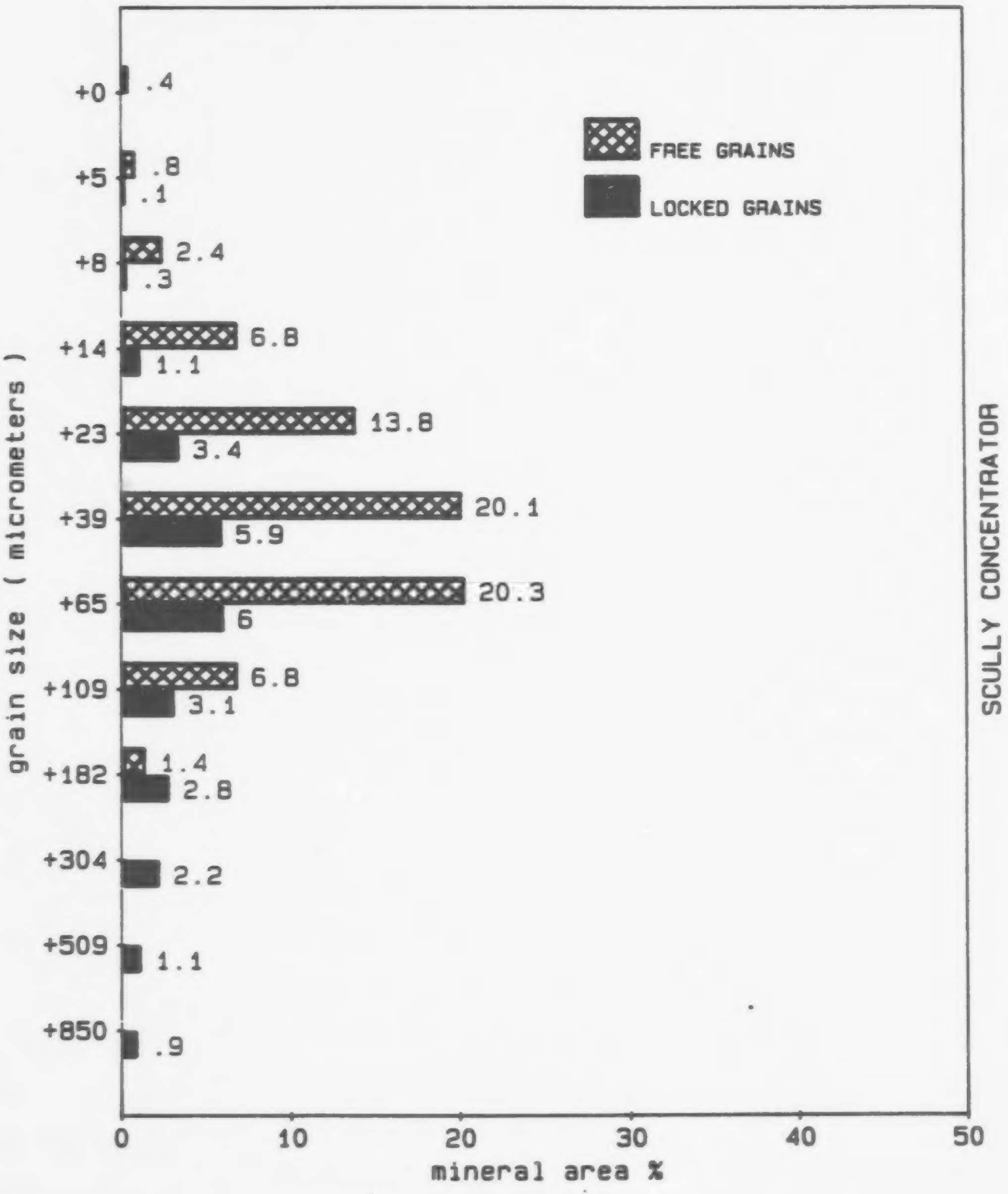
SIZE OF FREE AND LOCKED GRAINS



R.S.T. COMBINED FRACTIONS

HEMATITE AND MAGNETITE

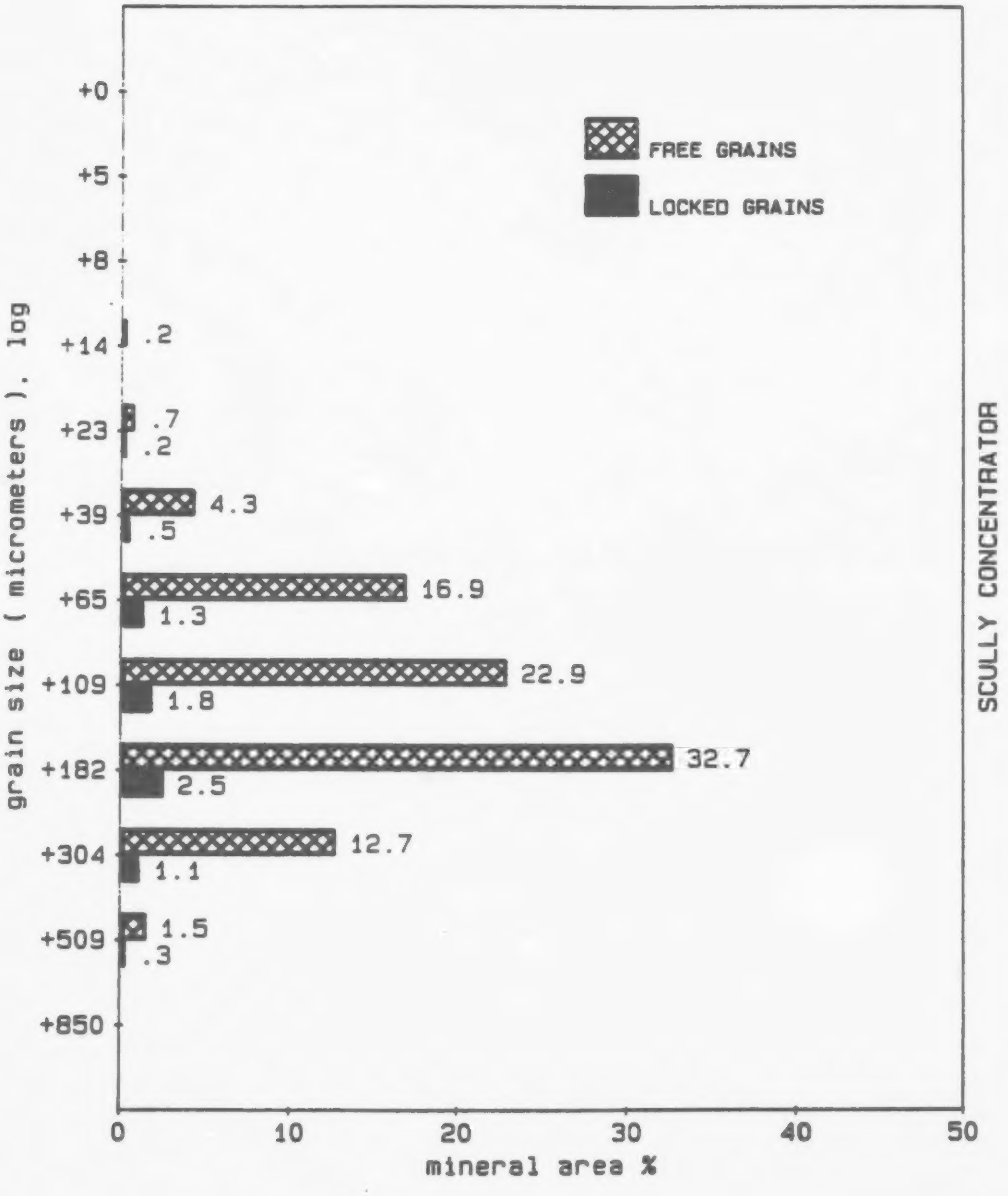
SIZE OF FREE AND LOCKED GRAINS



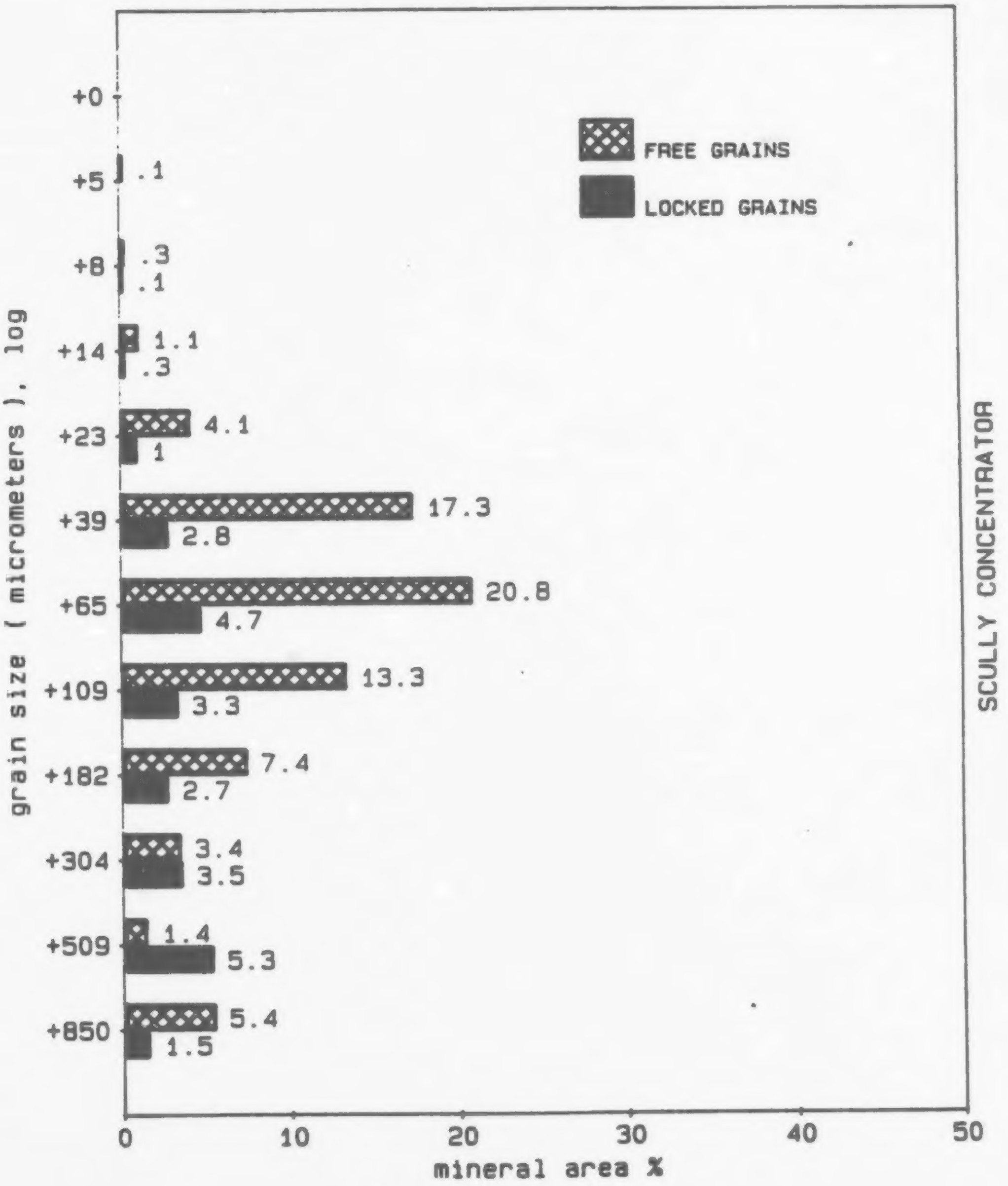
C.S.C. COMBINED FRACTIONS

HEMATITE AND MAGNETITE

SIZE OF FREE AND LOCKED GRAINS



C.S.T. COMBINED FRACTIONS
HEMATITE AND MAGNETITE
SIZE OF FREE AND LOCKED GRAINS



APPENDIX C-2

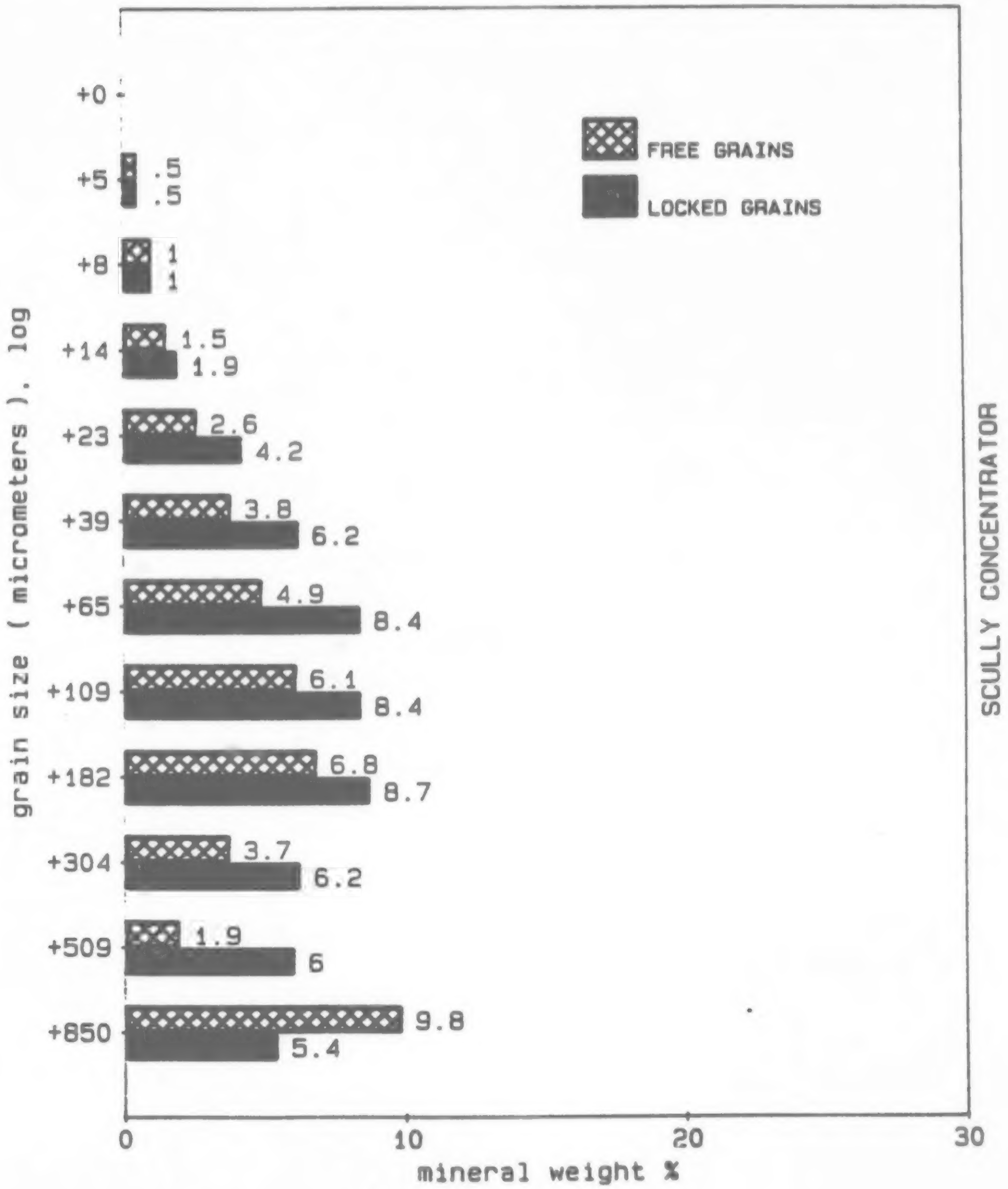
Scully Concentrator
Manganese Minerals and Manganese Goethite
Grain Size Distribution,
Combined Fractions,

TSU	RSC
SSO	RST
SSU	CSC
RSM	CST

T.S.U. COMBINED FRACTIONS

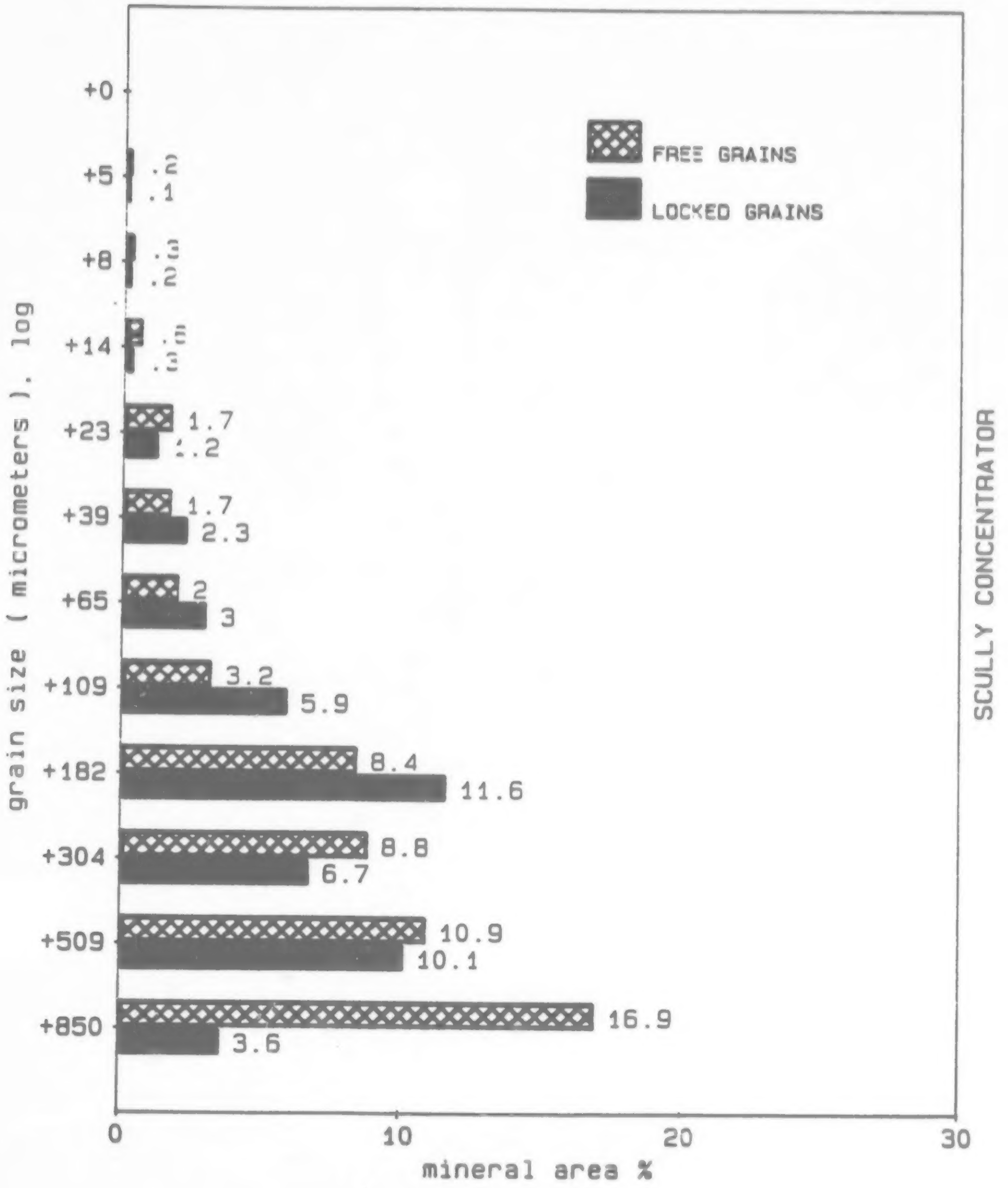
Mn MINERALS AND Mn GOETHITE

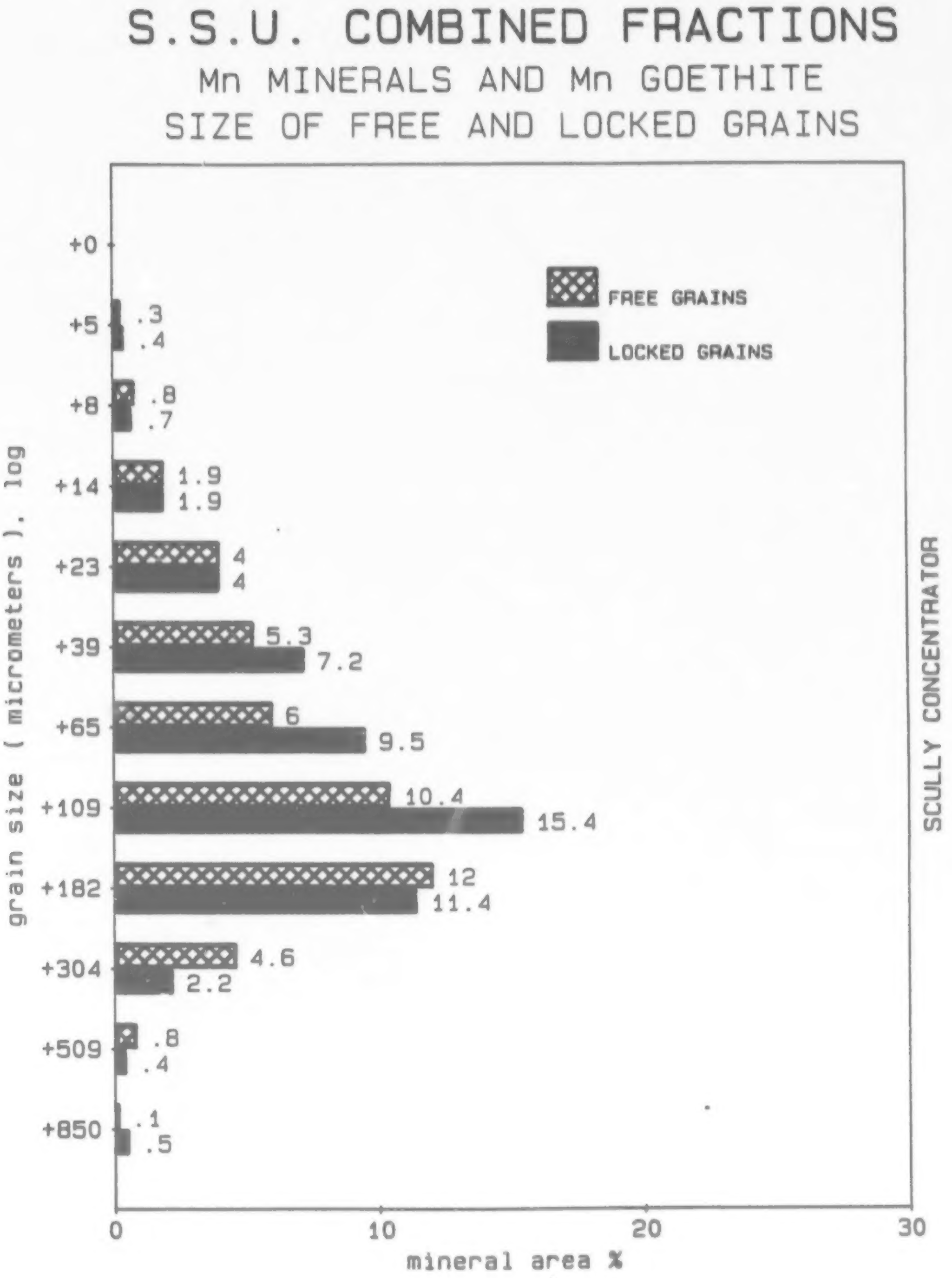
SIZE OF FREE AND LOCKED GRAINS



S.S.O. COMBINED FRACTIONS

Mn MINERALS AND Mn GOETHITE
SIZE OF FREE AND LOCKED GRAINS



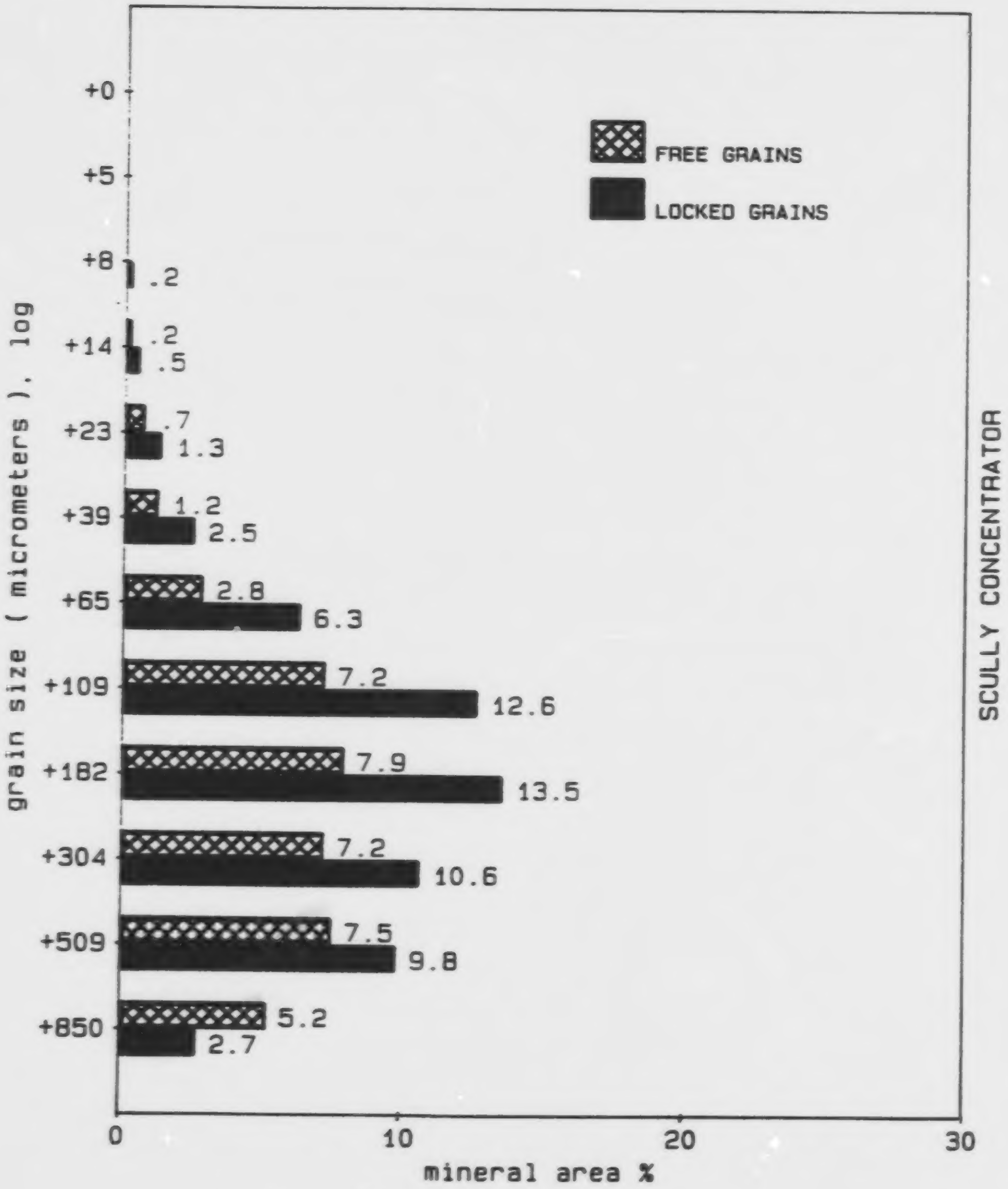


S.S.U. COMBINED FRACTIONS
Mn MINERALS AND Mn GOETHITE
SIZE OF FREE AND LOCKED GRAINS

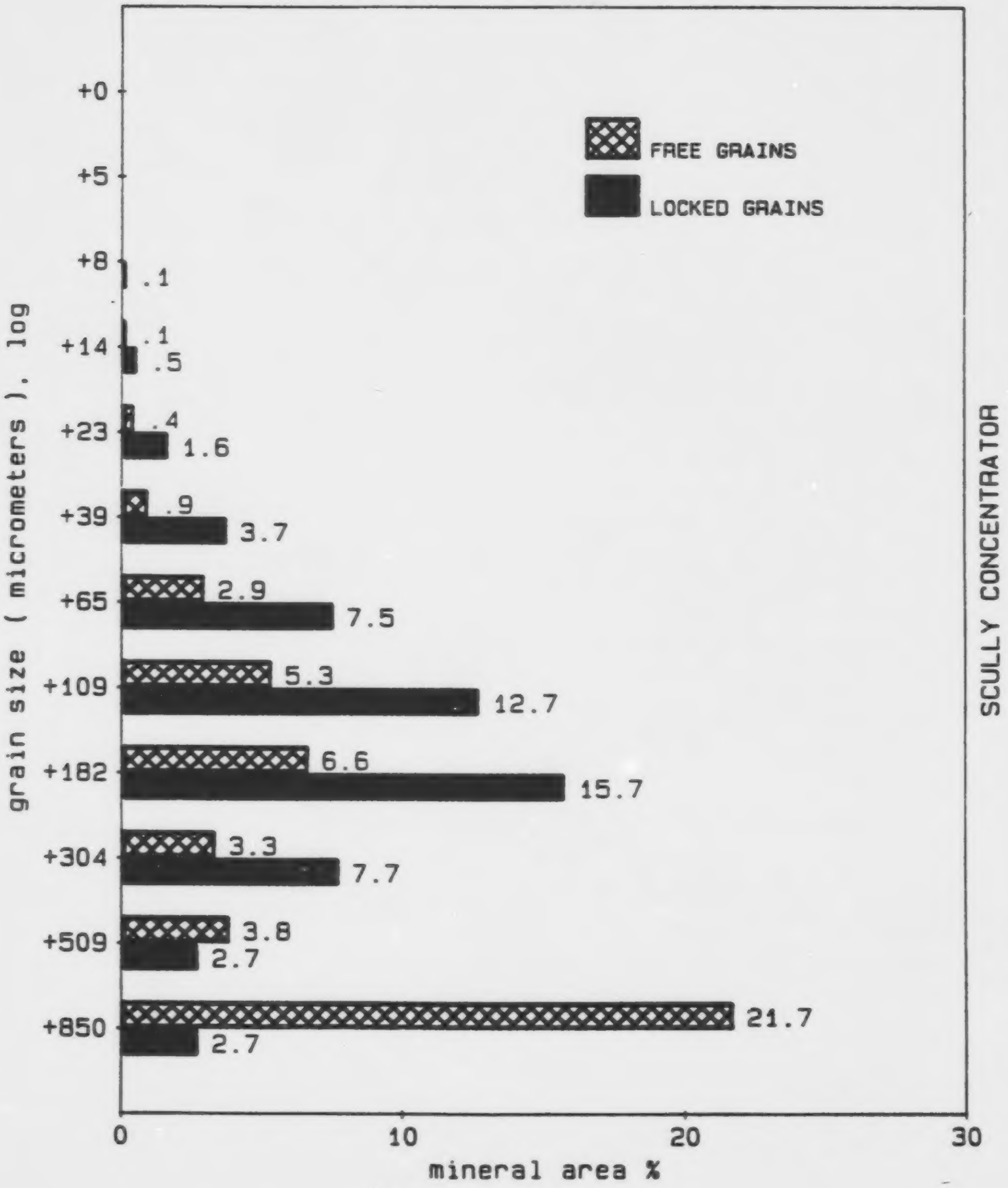
R.S.M. COMBINED FRACTIONS

Mn MINERALS AND Mn GOETHITE

SIZE OF FREE AND LOCKED GRAINS



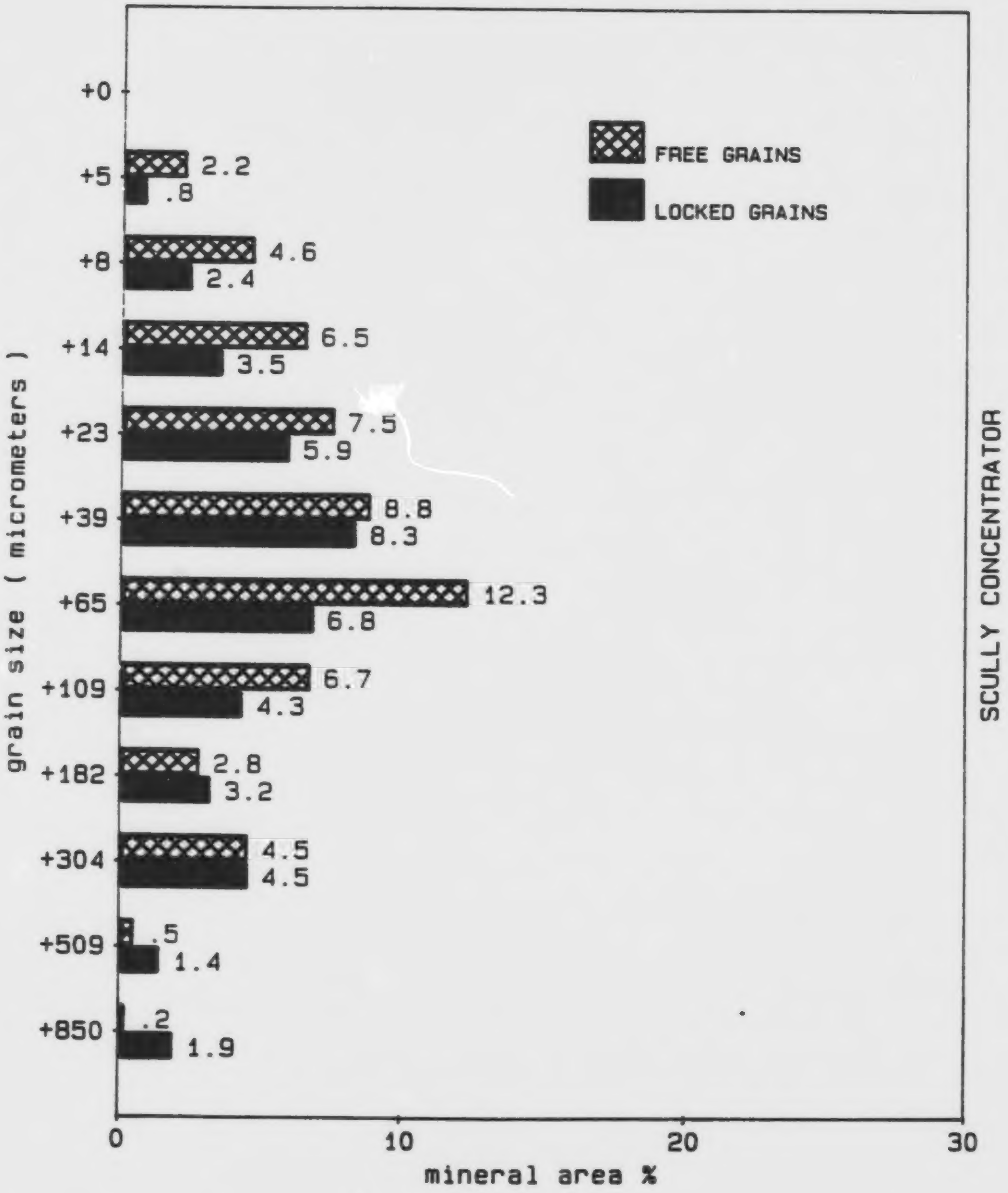
R.S.C. COMBINED FRACTIONS
Mn MINERALS AND Mn GOETHITE
SIZE OF FREE AND LOCKED GRAINS



R.S.T. COMBINED FRACTIONS

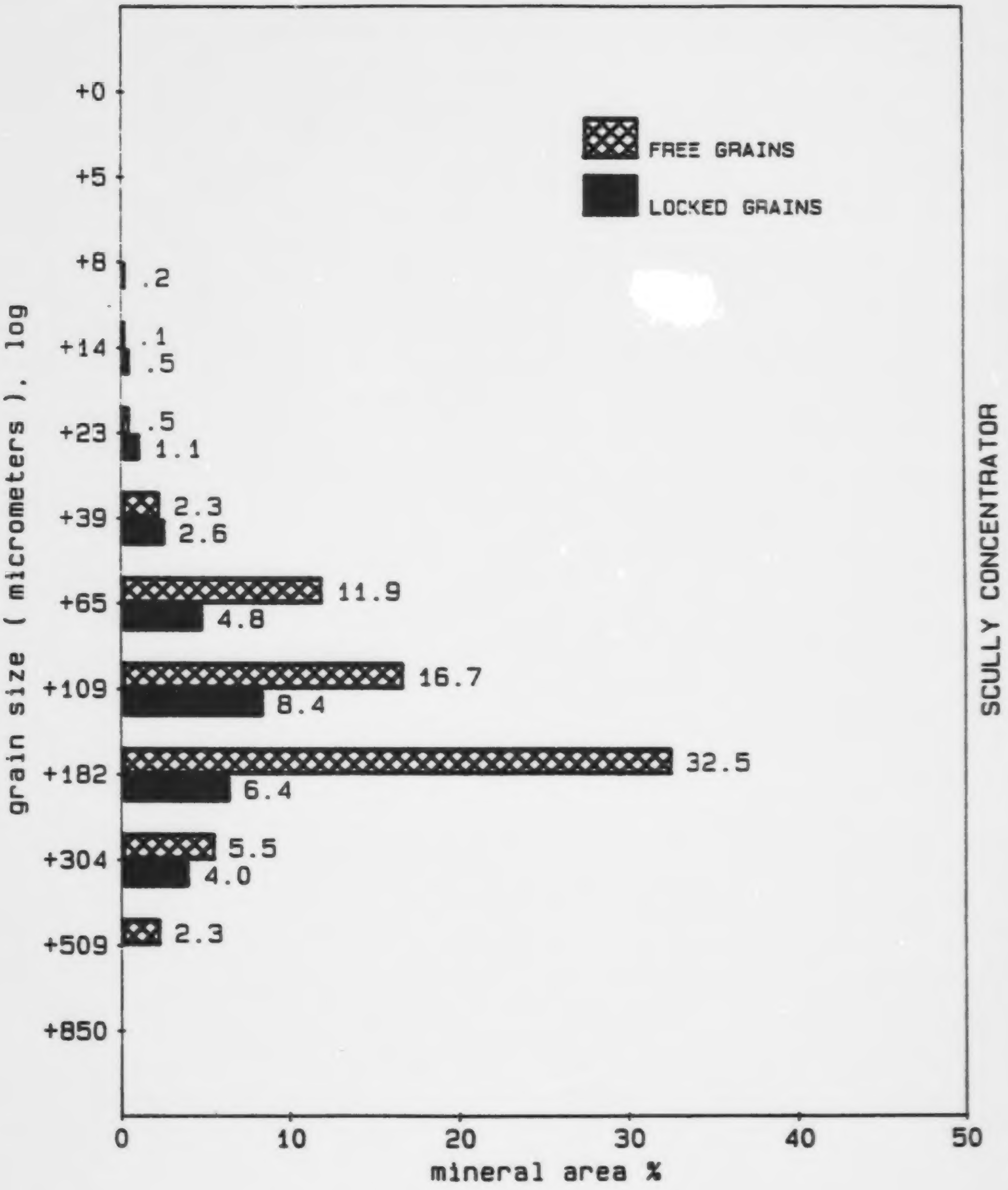
Mn MINERALS AND Mn GOETHITE

SIZE OF FREE AND LOCKED GRAINS



C.S.C. COMBINED FRACTIONS

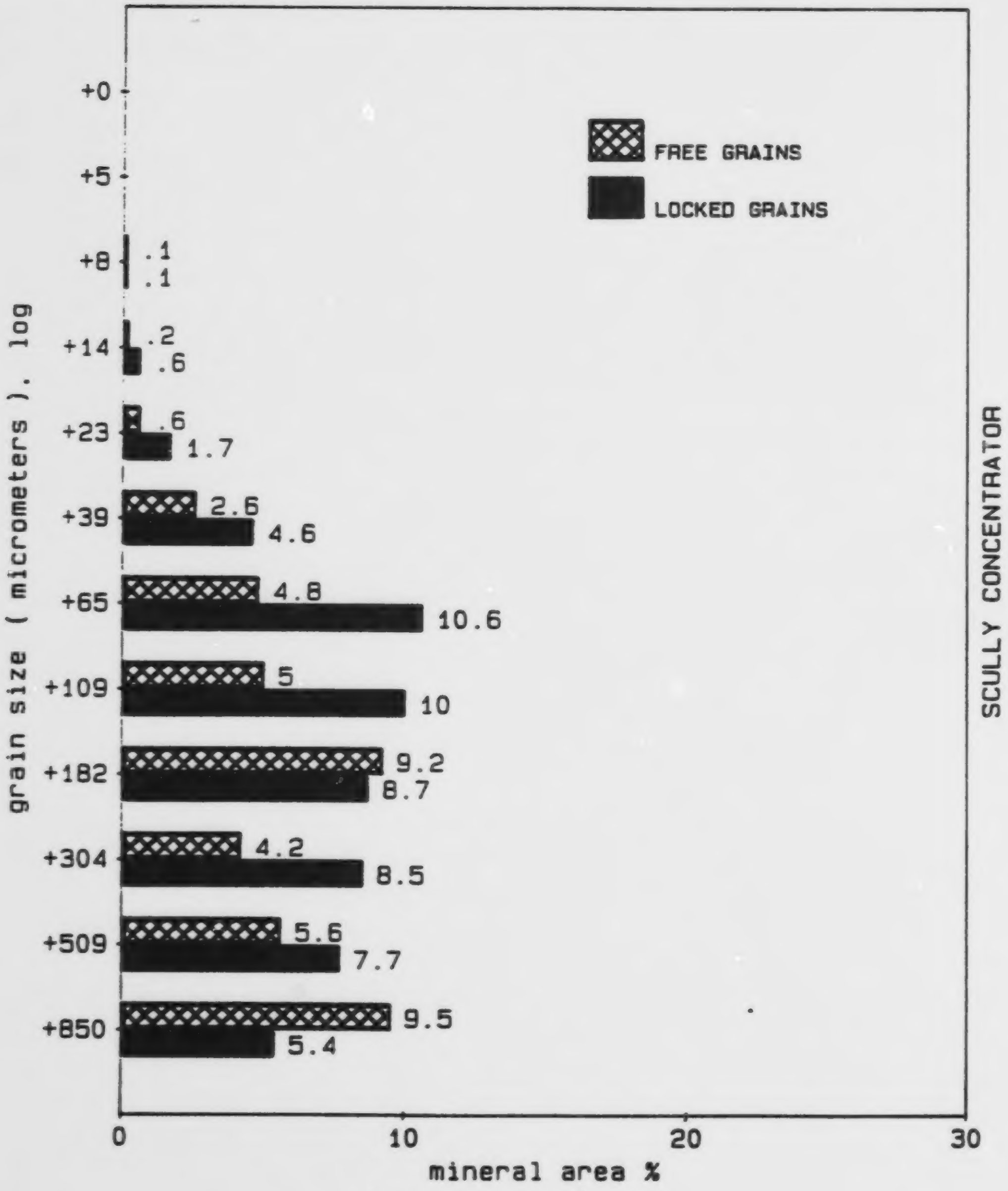
Mn MINERALS AND Mn GOETHITE
SIZE OF FREE AND LOCKED GRAINS



C.S.T. COMBINED FRACTIONS

Mn MINERALS AND Mn GOETHITE

SIZE OF FREE AND LOCKED GRAINS



APPENDIX C-3

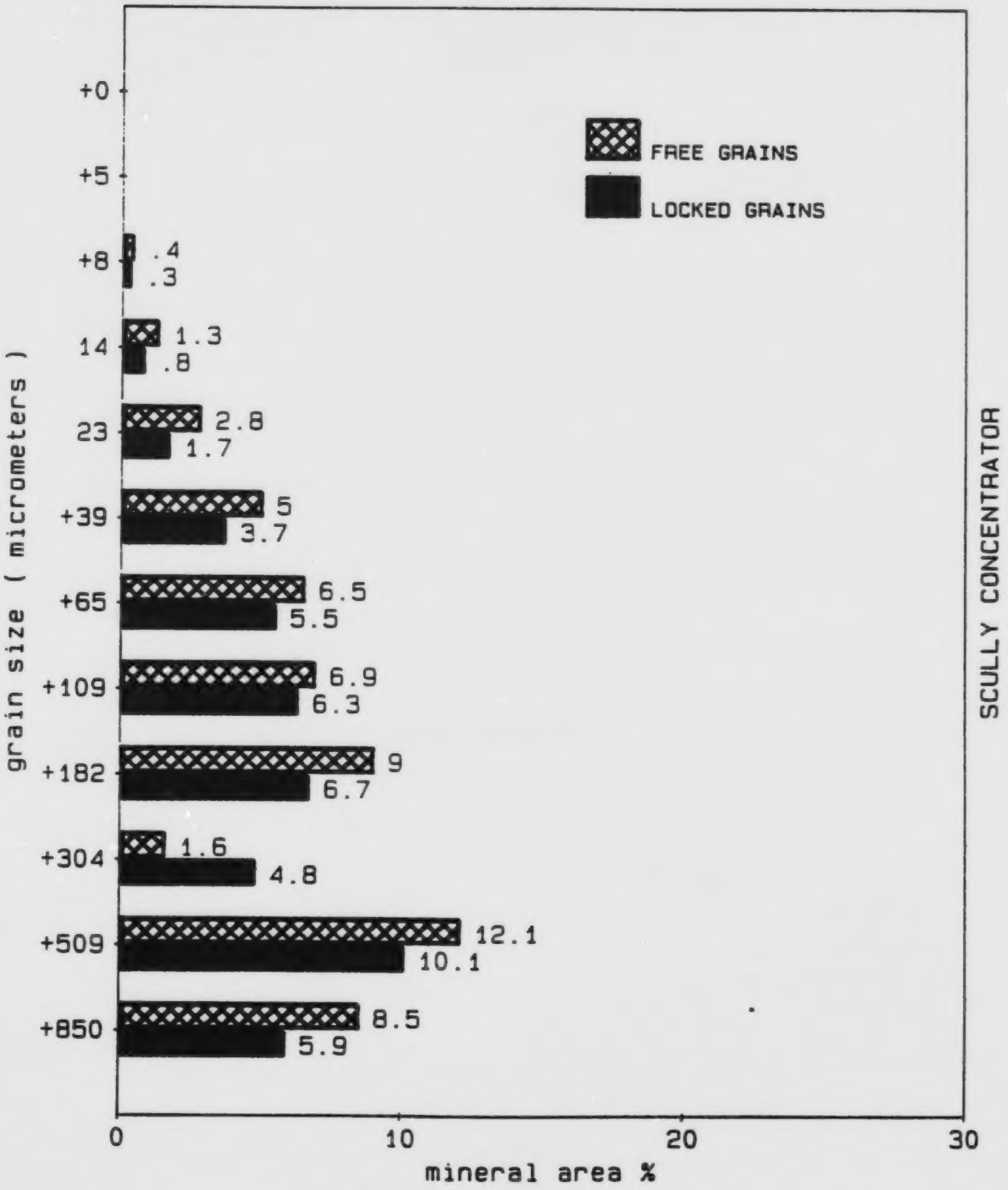
Scully Concentrator
Goethite Free of Manganese
Grain Size Distribution,
Combined Fractions,

TSU
SSO
SSU
RSM
RSC
RST
CSC
CST

T.S.U. COMBINED FRACTIONS

GOETHITE FREE OF Mn

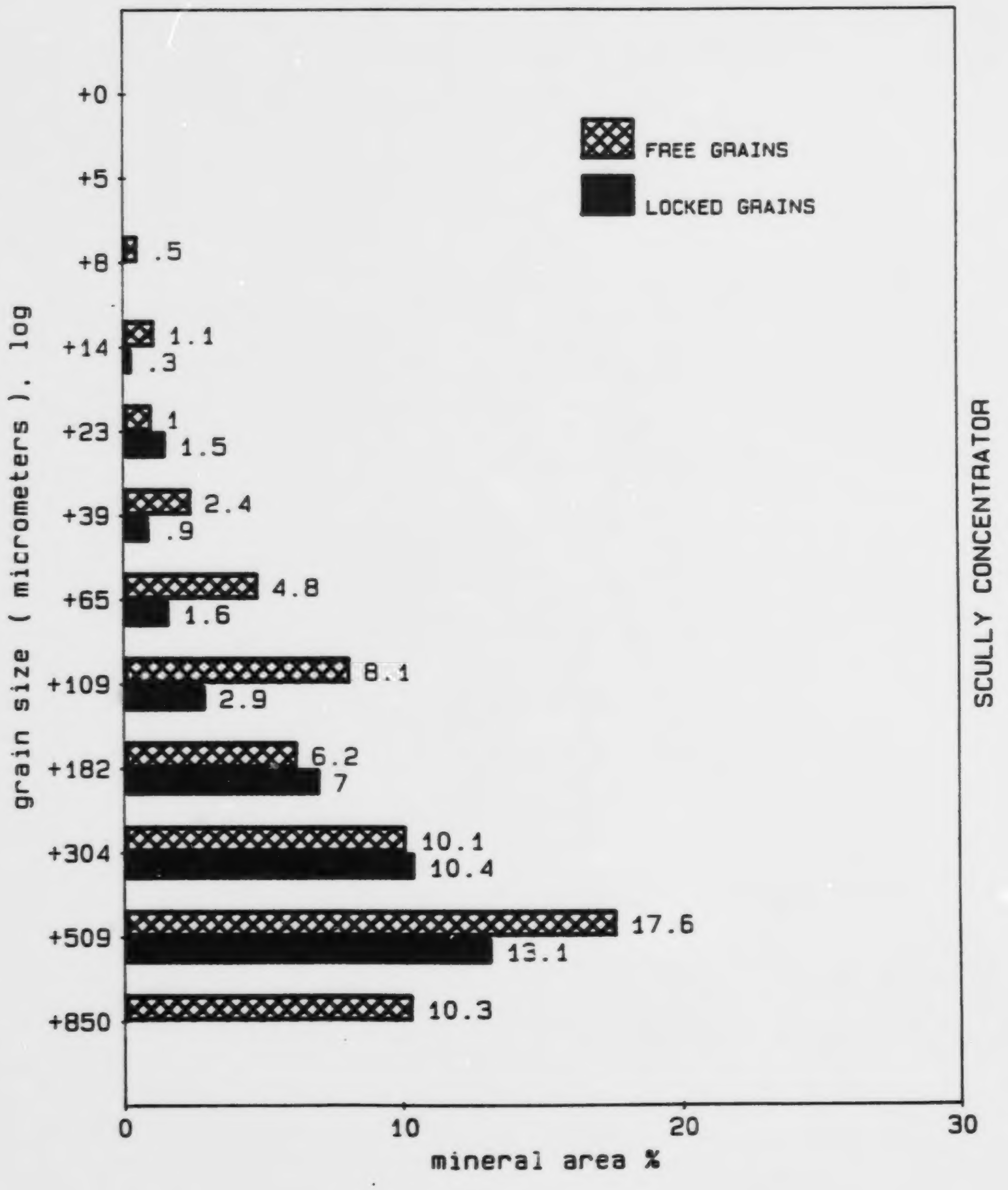
SIZE OF FREE AND LOCKED GRAINS



S.S.O. COMBINED FRACTIONS

GOETHITE FREE OF Mn

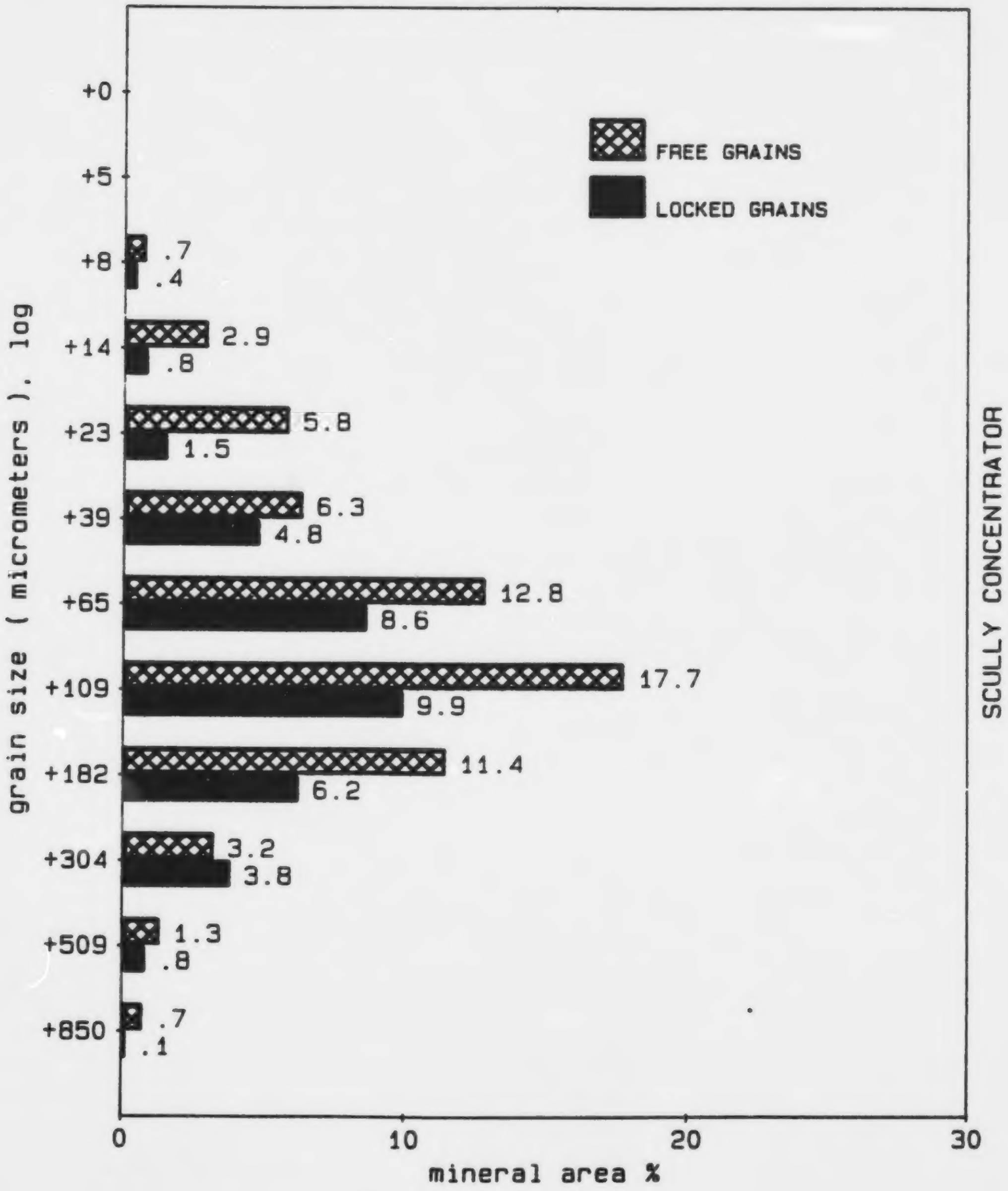
SIZE OF FREE AND LOCKED GRAINS



S.S.U. COMBINED FRACTIONS

GOETHITE FREE OF Mn

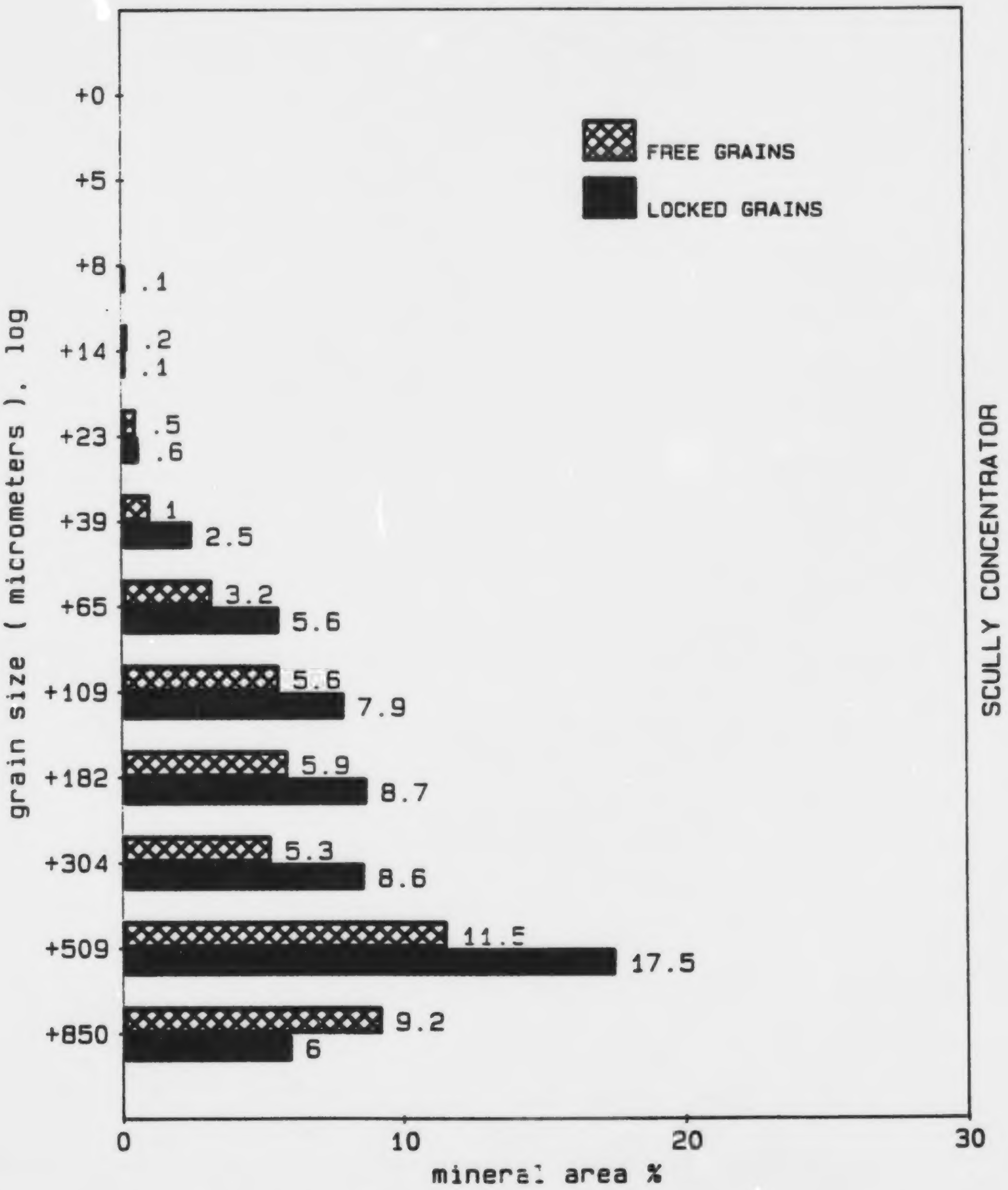
SIZE OF FREE AND LOCKED GRAINS



R.S.M. COMBINED FRACTIONS

GOETHITE FREE OF Mn

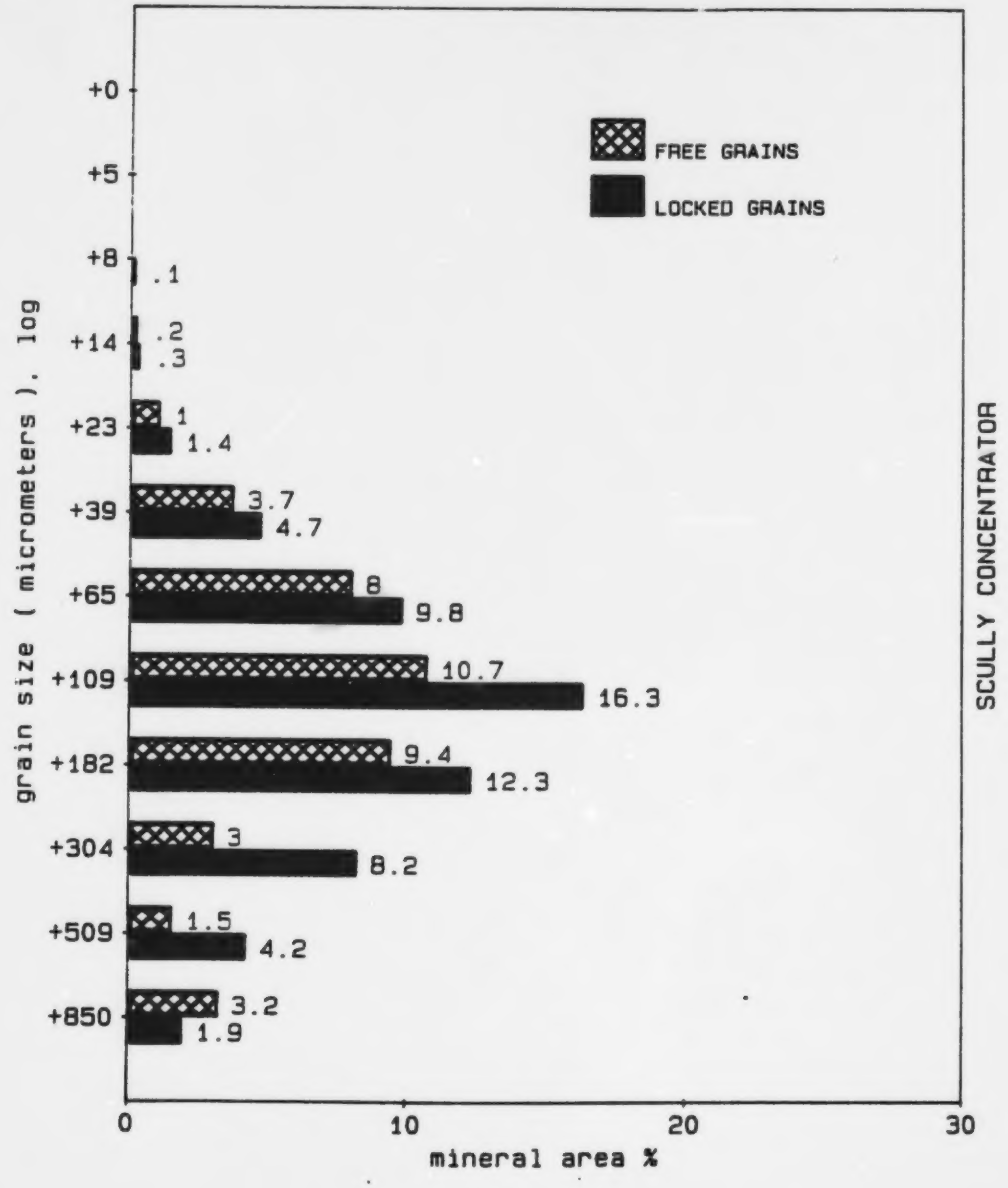
SIZE OF FREE AND LOCKED GRAINS



R.S.C. COMBINED FRACTIONS

GOETHITE FREE OF Mn

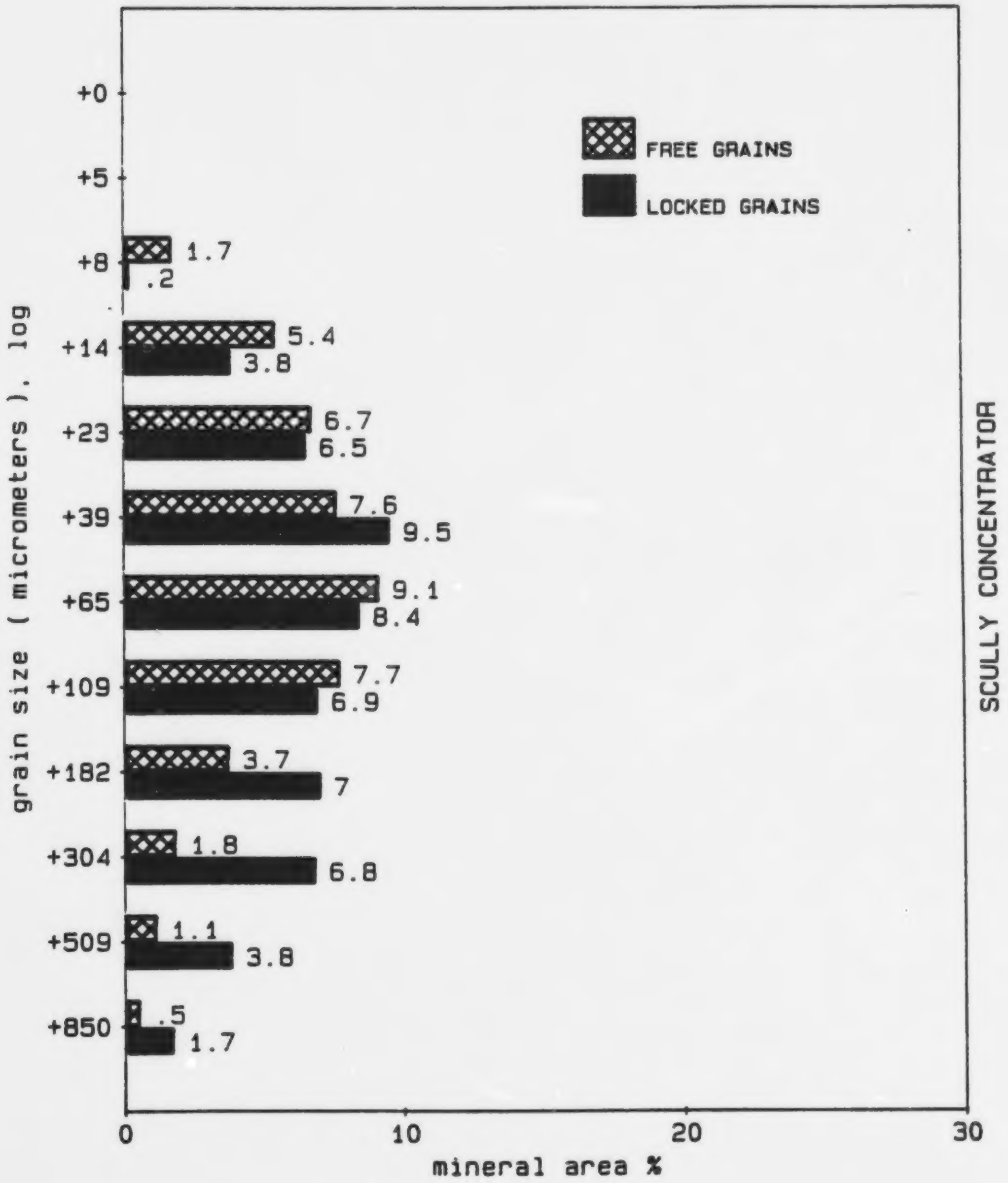
SIZE OF FREE AND LOCKED GRAINS



R.S.T. COMBINED FRACTIONS

GOETHITE FREE OF Mn

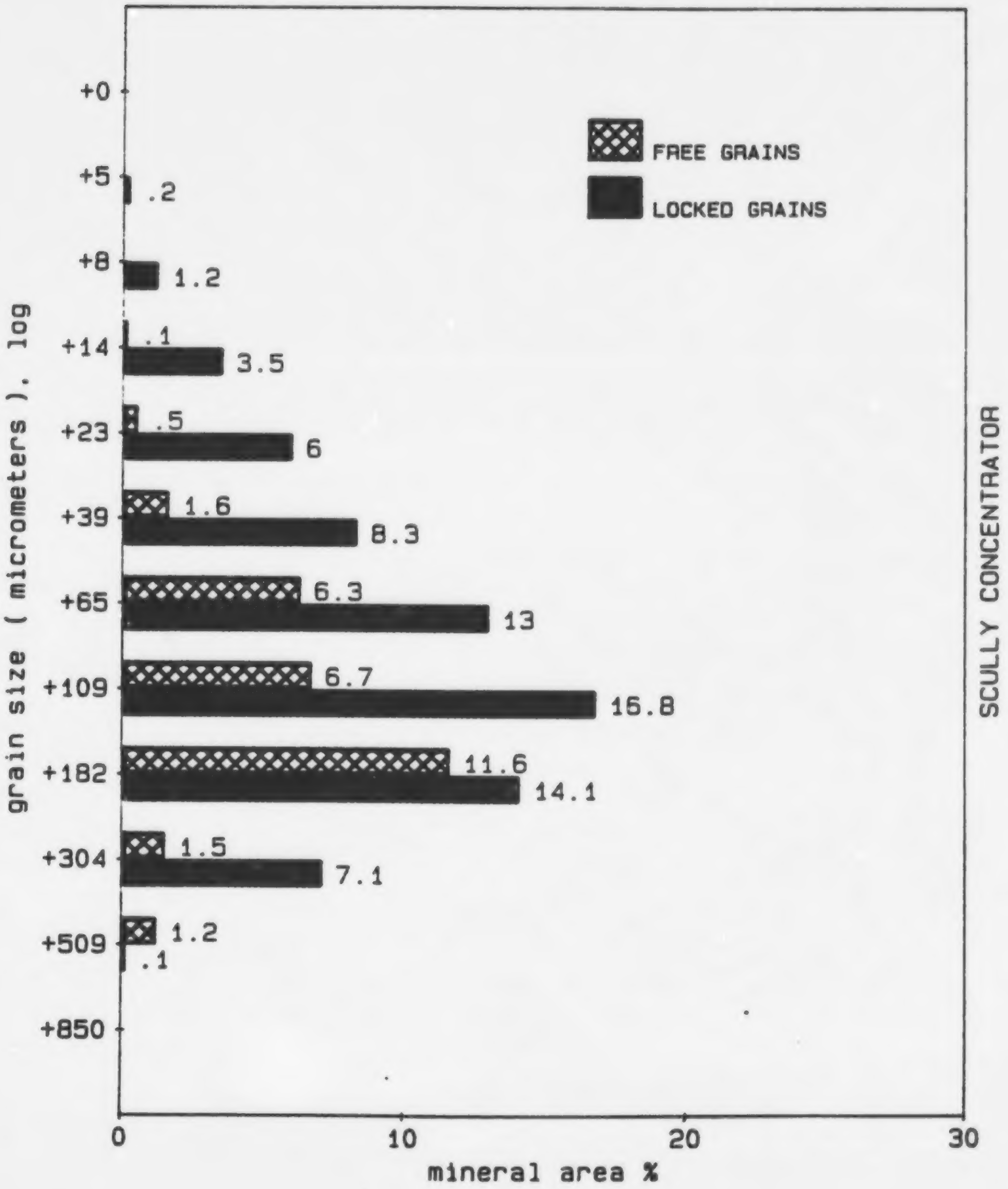
SIZE OF FREE AND LOCKED GRAINS



C.S.C. COMBINED FRACTIONS

GOETHITE FREE OF Mn

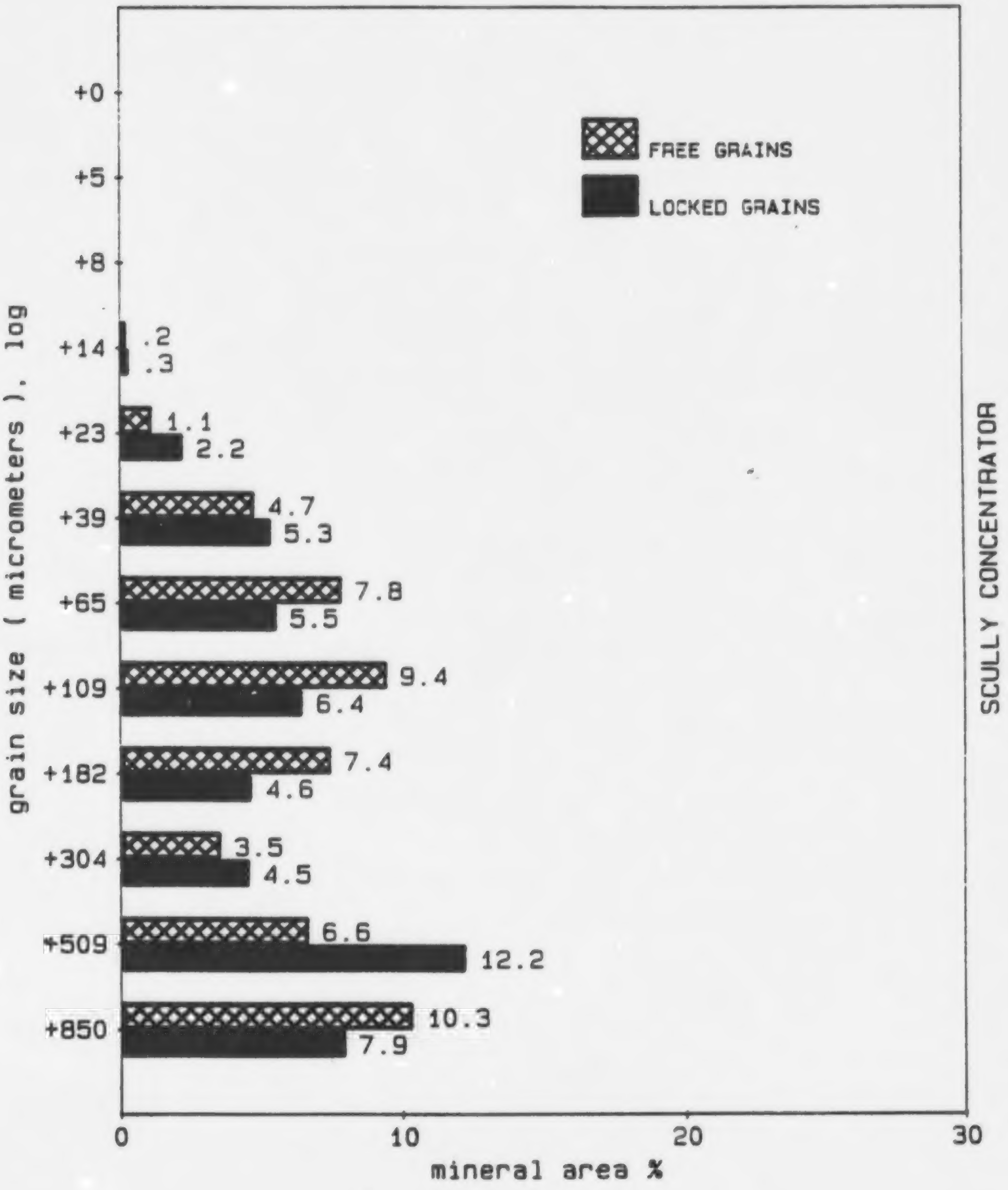
SIZE OF FREE AND LOCKED GRAINS



C.S.T. COMBINED FRACTIONS

GOETHITE FREE OF Mn

SIZE OF FREE AND LOCKED GRAINS

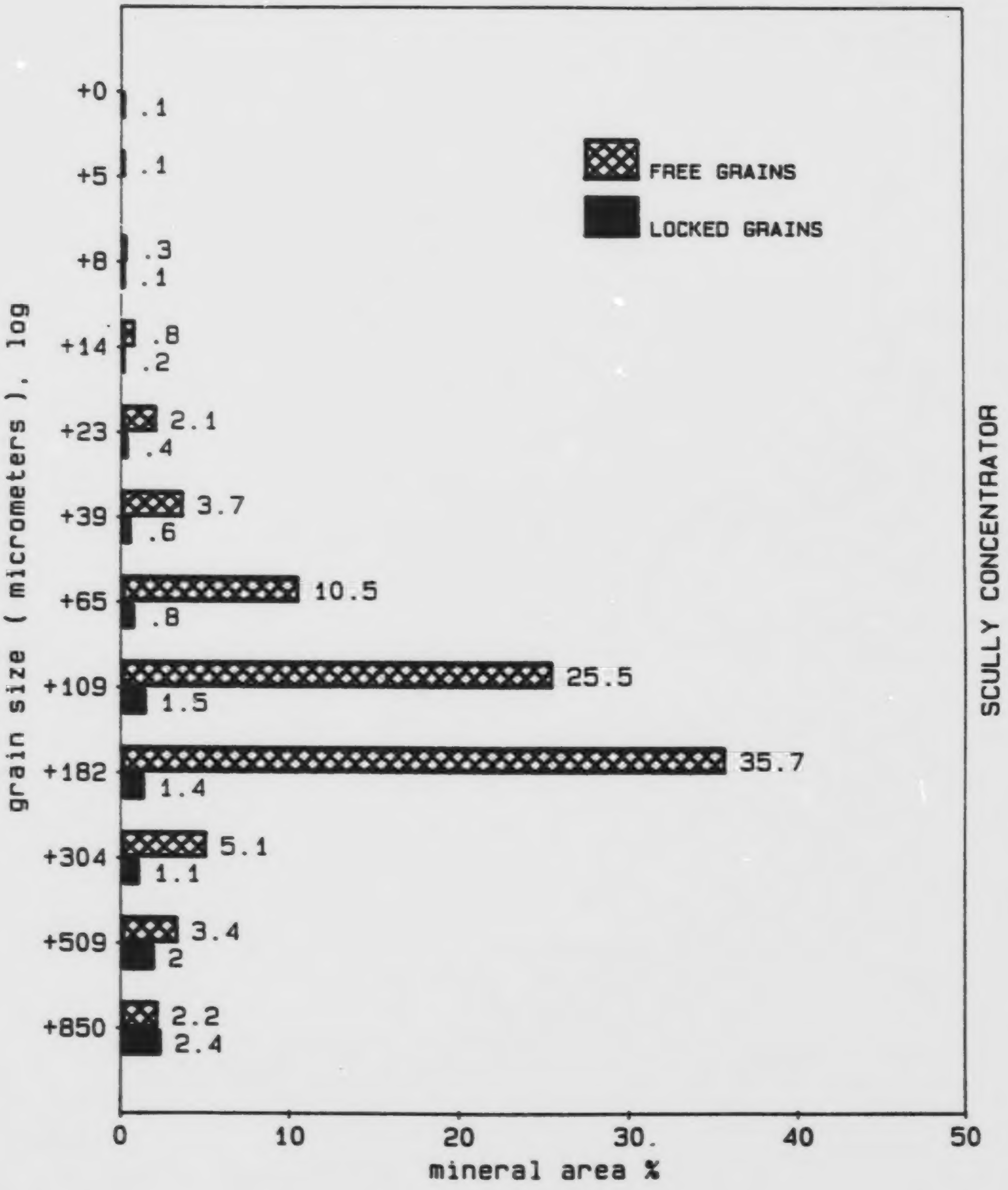


APPENDIX C-4

Scully Concentrator
Silicates
Grain Size Distribution, Combined Fractions

TSU
SSO
SSU
RSM
RSC
RST
CSC
CST

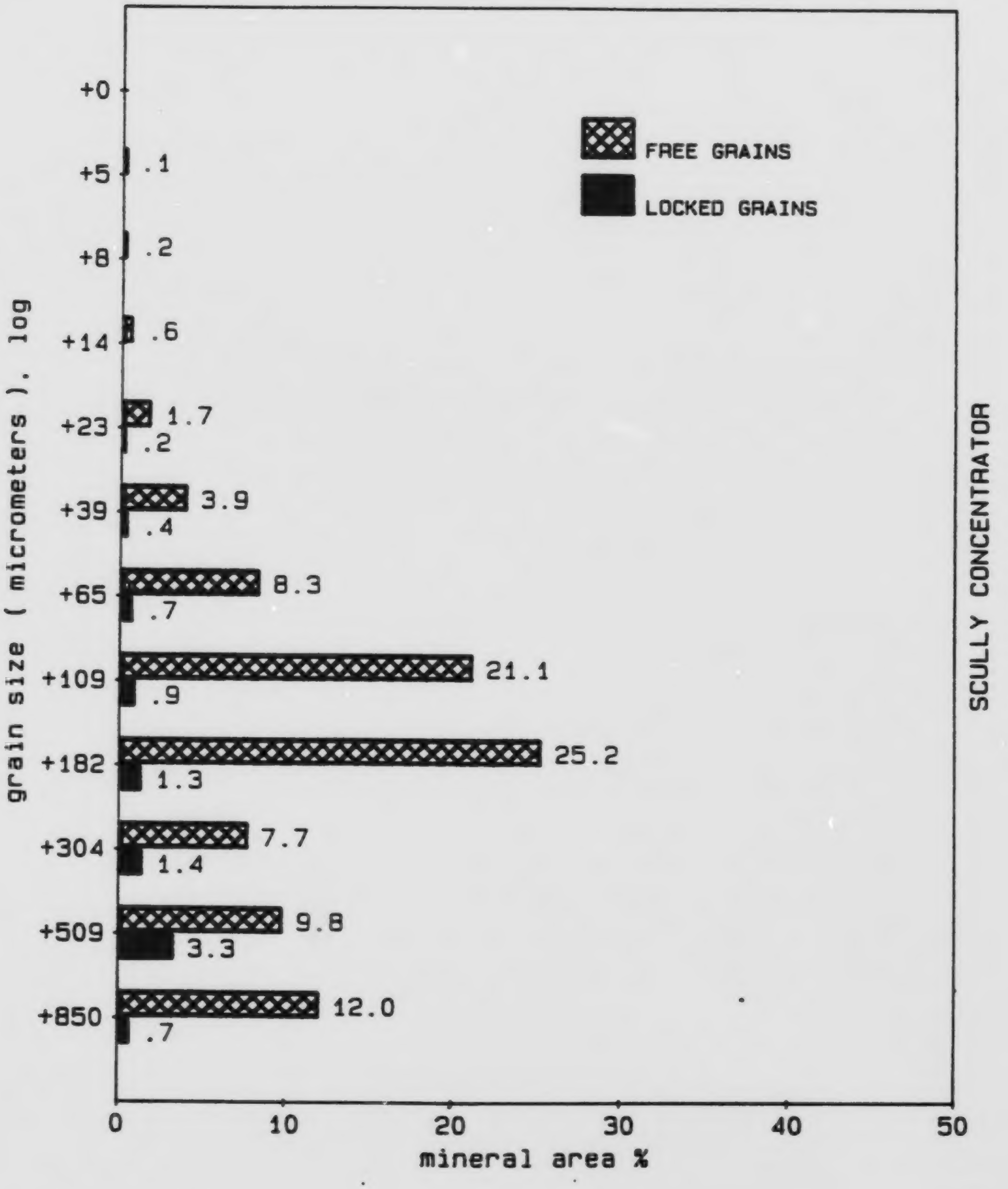
T.S.U. COMBINED FRACTIONS
SILICATES
SIZE OF FREE AND LOCKED GRAINS



S.S.O. COMBINED FRACTIONS

SILICATES

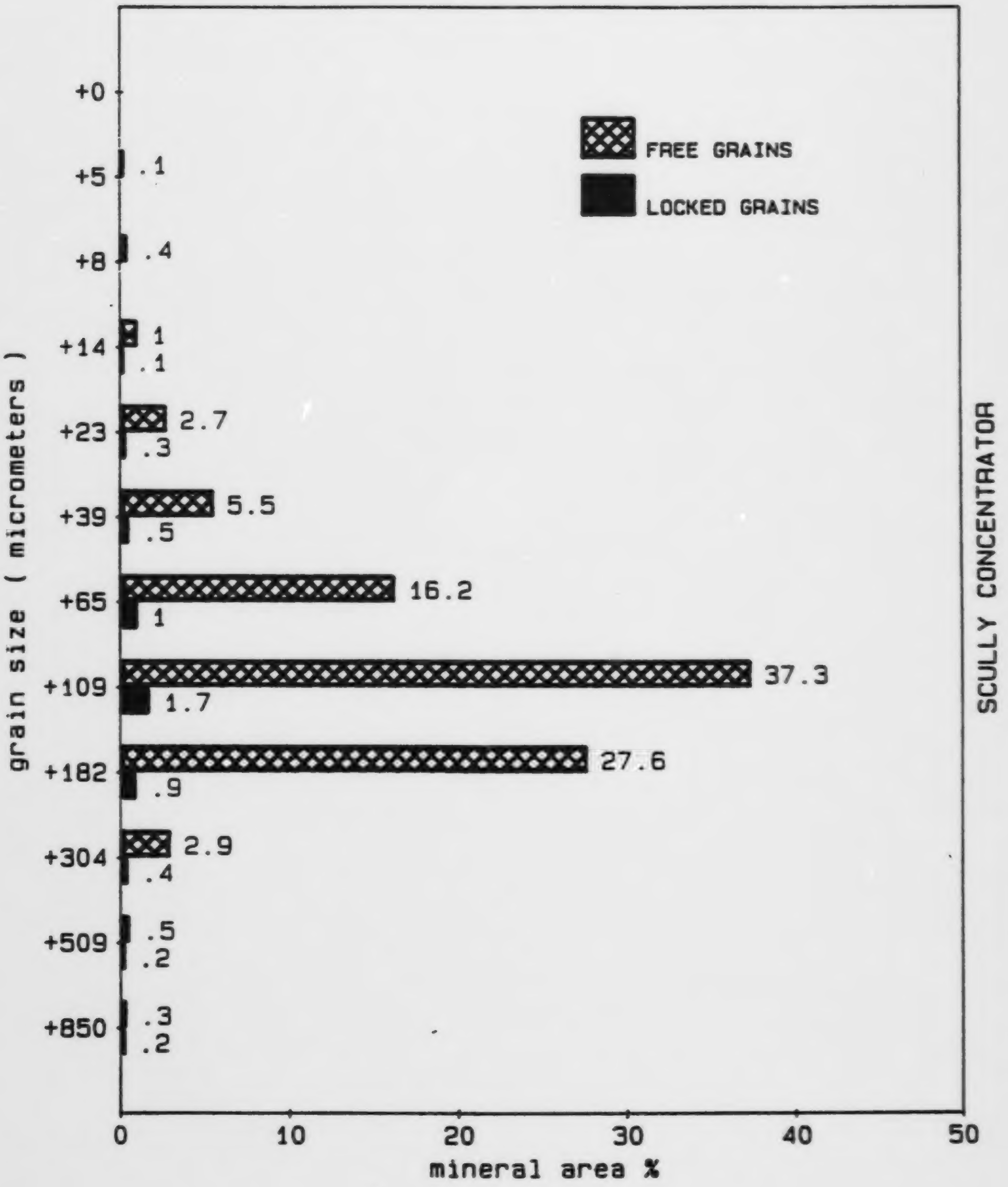
SIZE OF FREE AND LOCKED GRAINS



S.S.U. COMBINED FRACTIONS

SILICATES

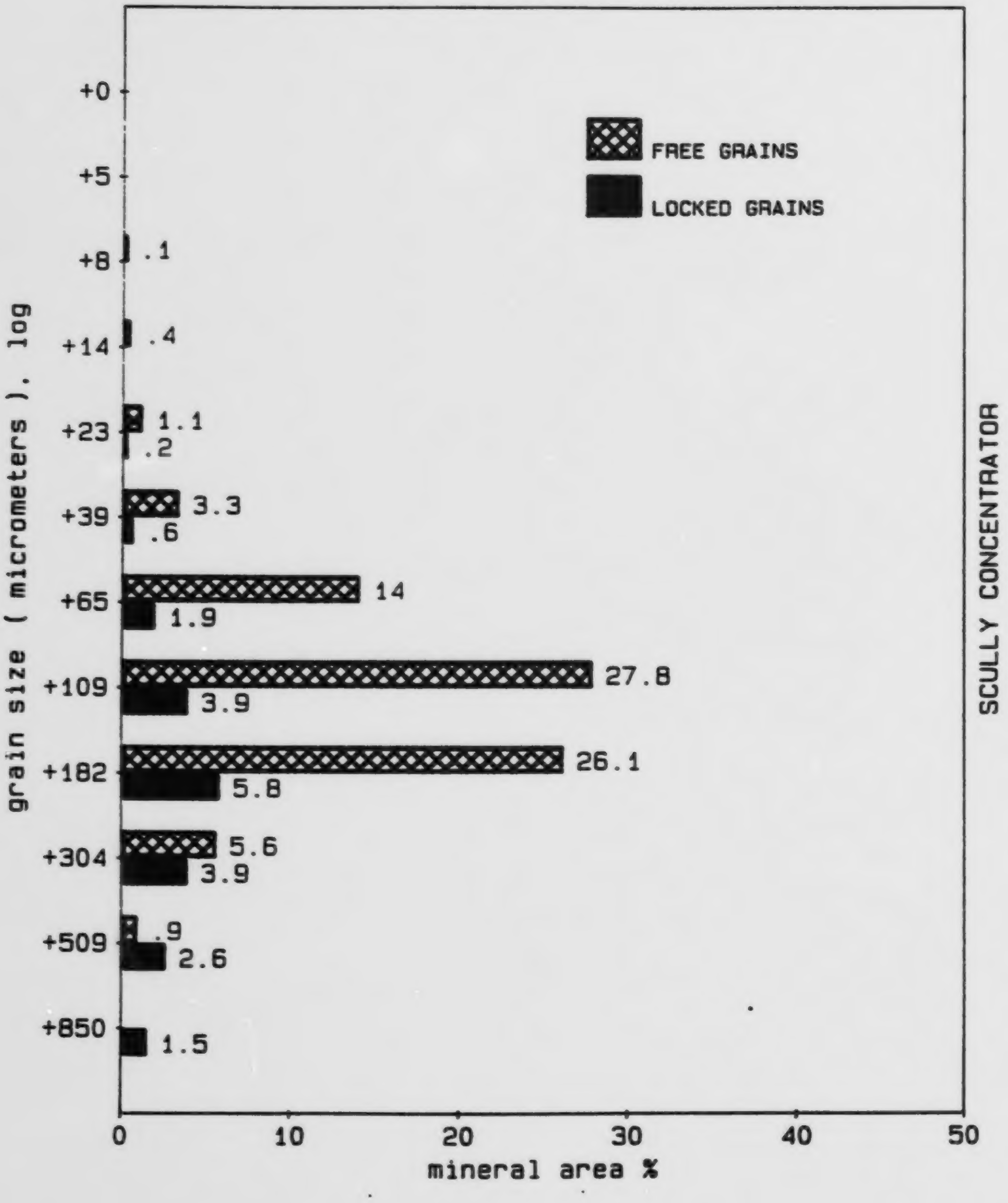
SIZE OF FREE AND LOCKED GRAINS



R.S.M. COMBINED FRACTIONS

SILICATES

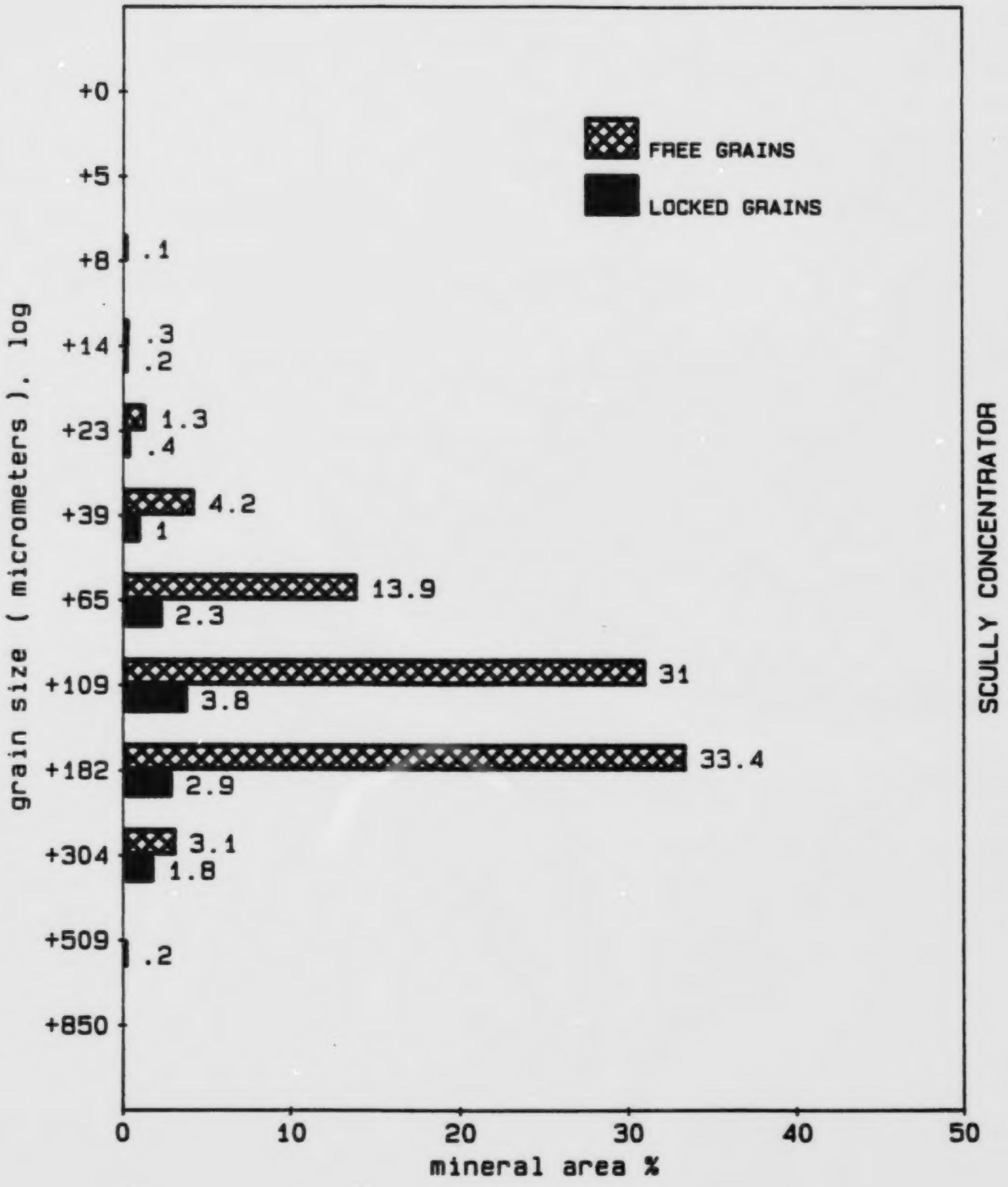
SIZE OF FREE AND LOCKED GRAINS



R.S.C. COMBINED FRACTIONS

SILICATES

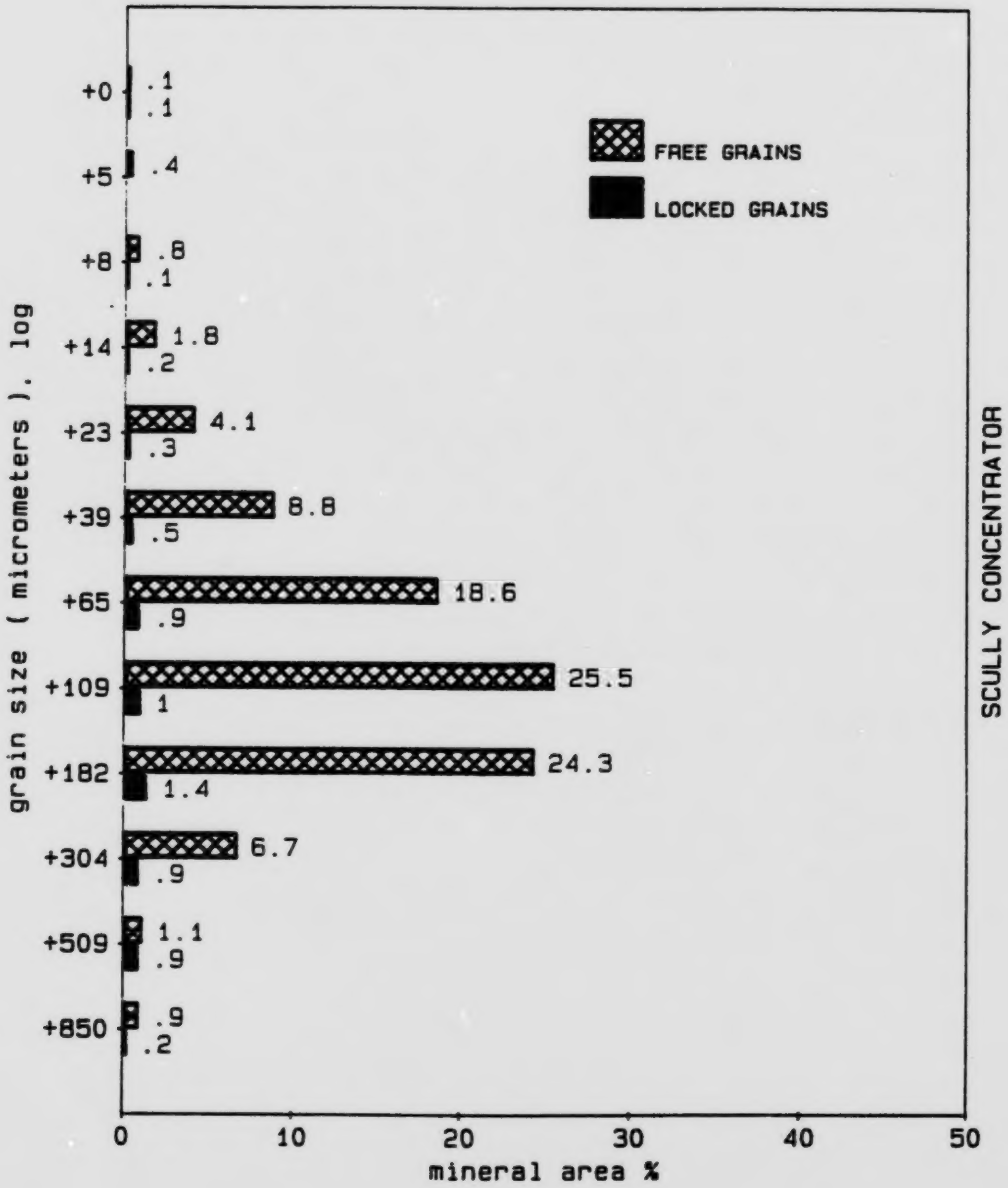
SIZE OF FREE AND LOCKED GRAINS



R.S.T. COMBINED FRACTIONS

SILICATES

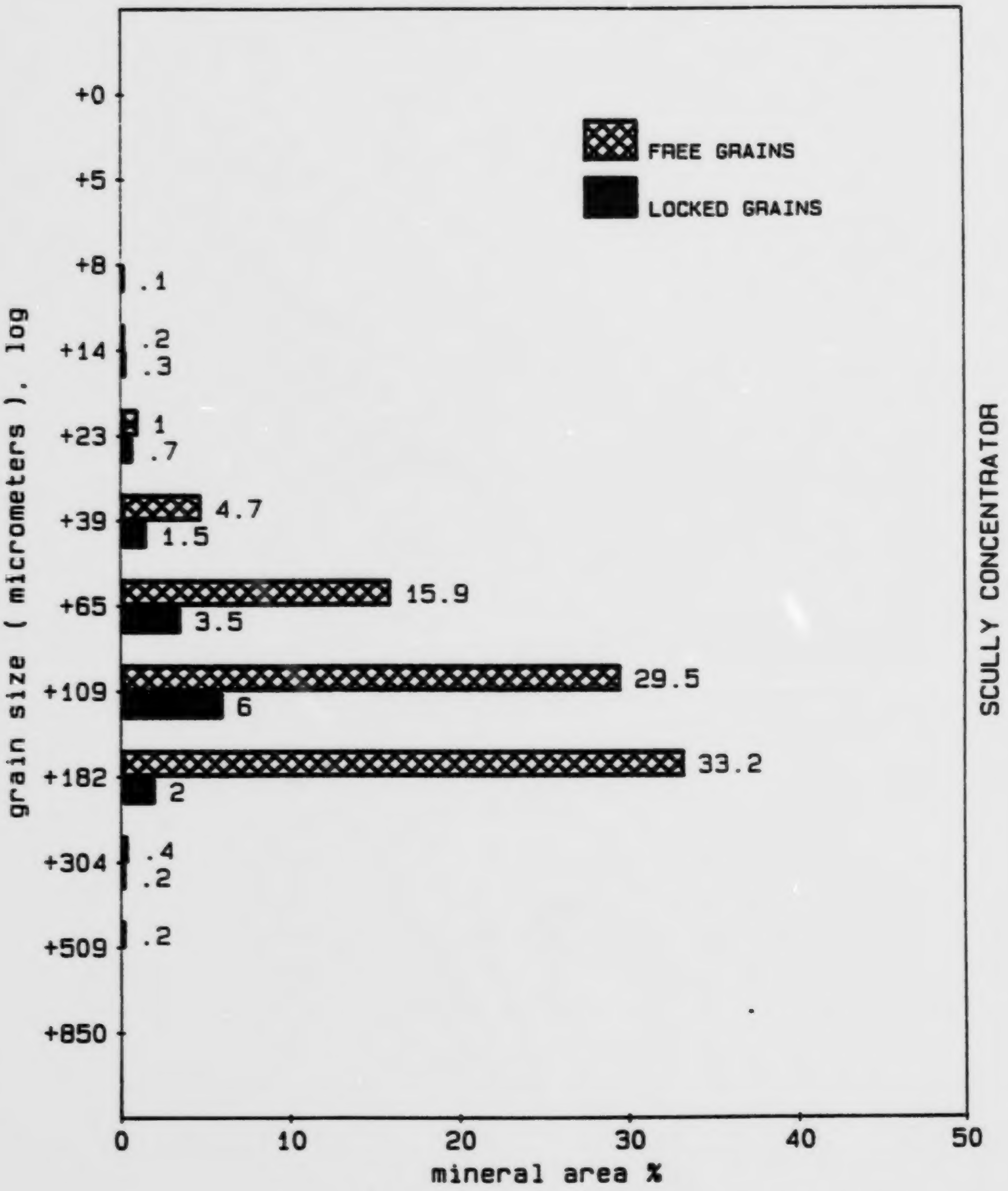
SIZE OF FREE AND LOCKED GRAINS



C.S.C. COMBINED FRACTIONS

SILICATES

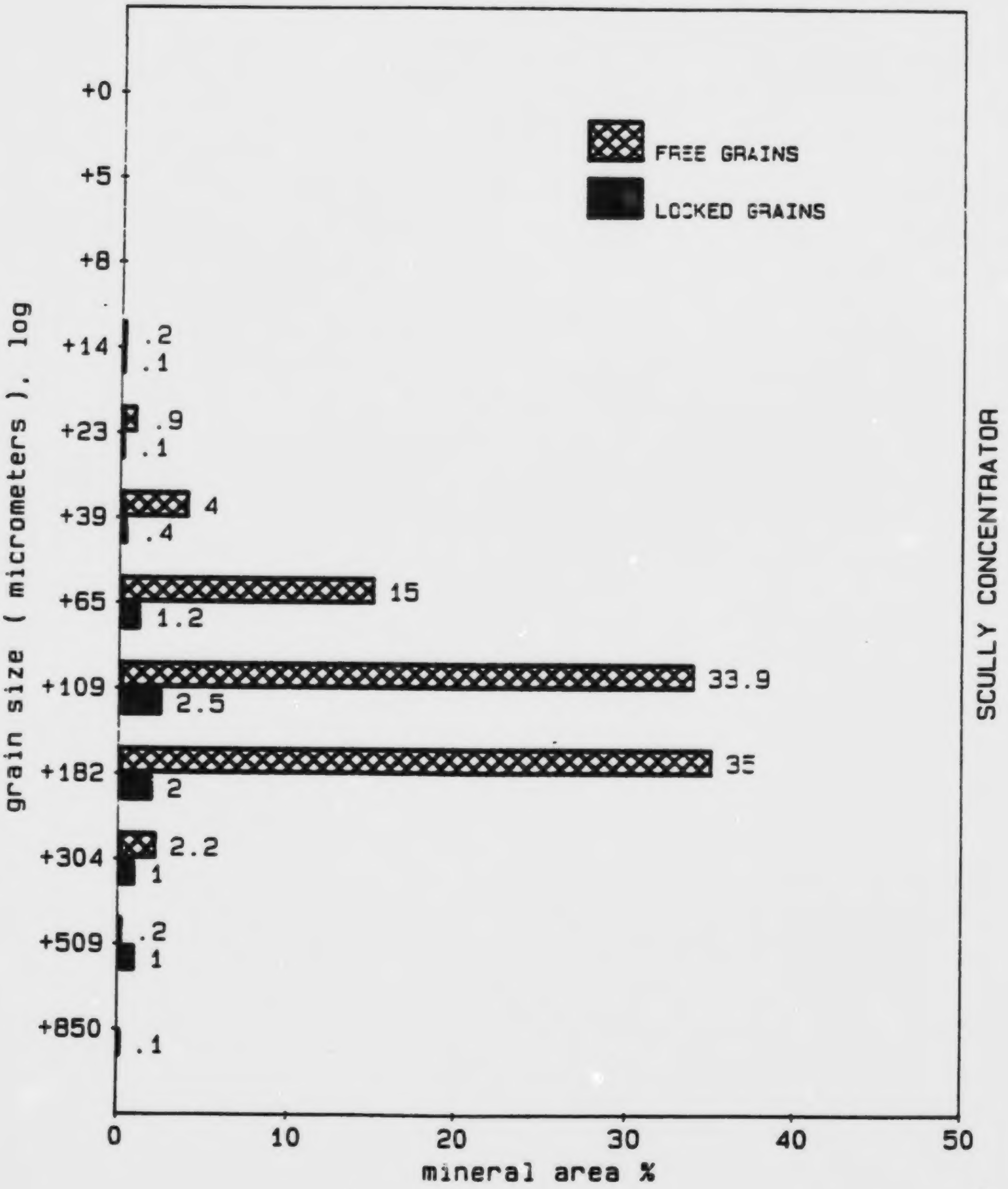
SIZE OF FREE AND LOCKED GRAINS



C.S.T. COMBINED FRACTIONS

SILICATES

SIZE OF FREE AND LOCKED GRAINS



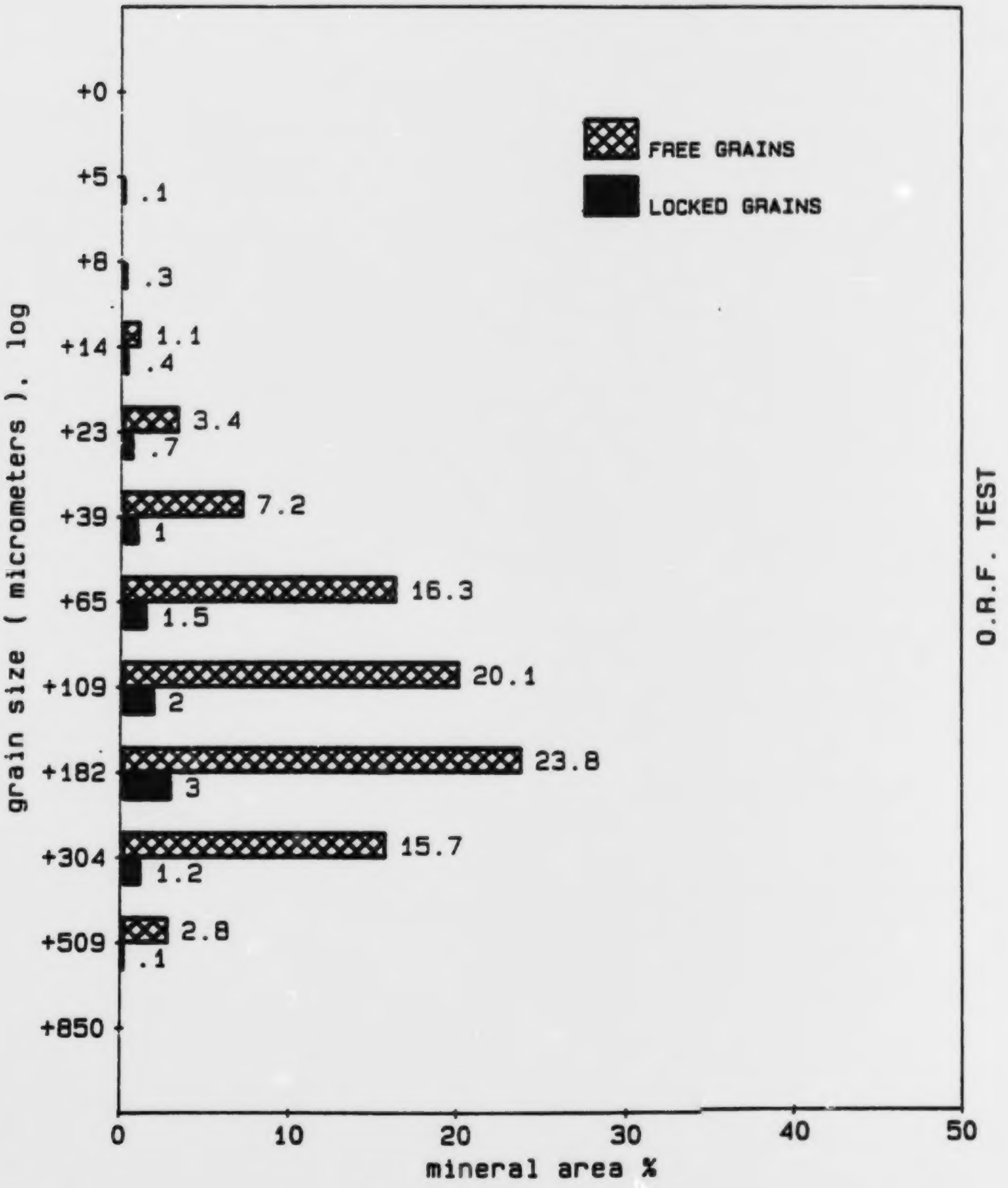
APPENDIX D-1

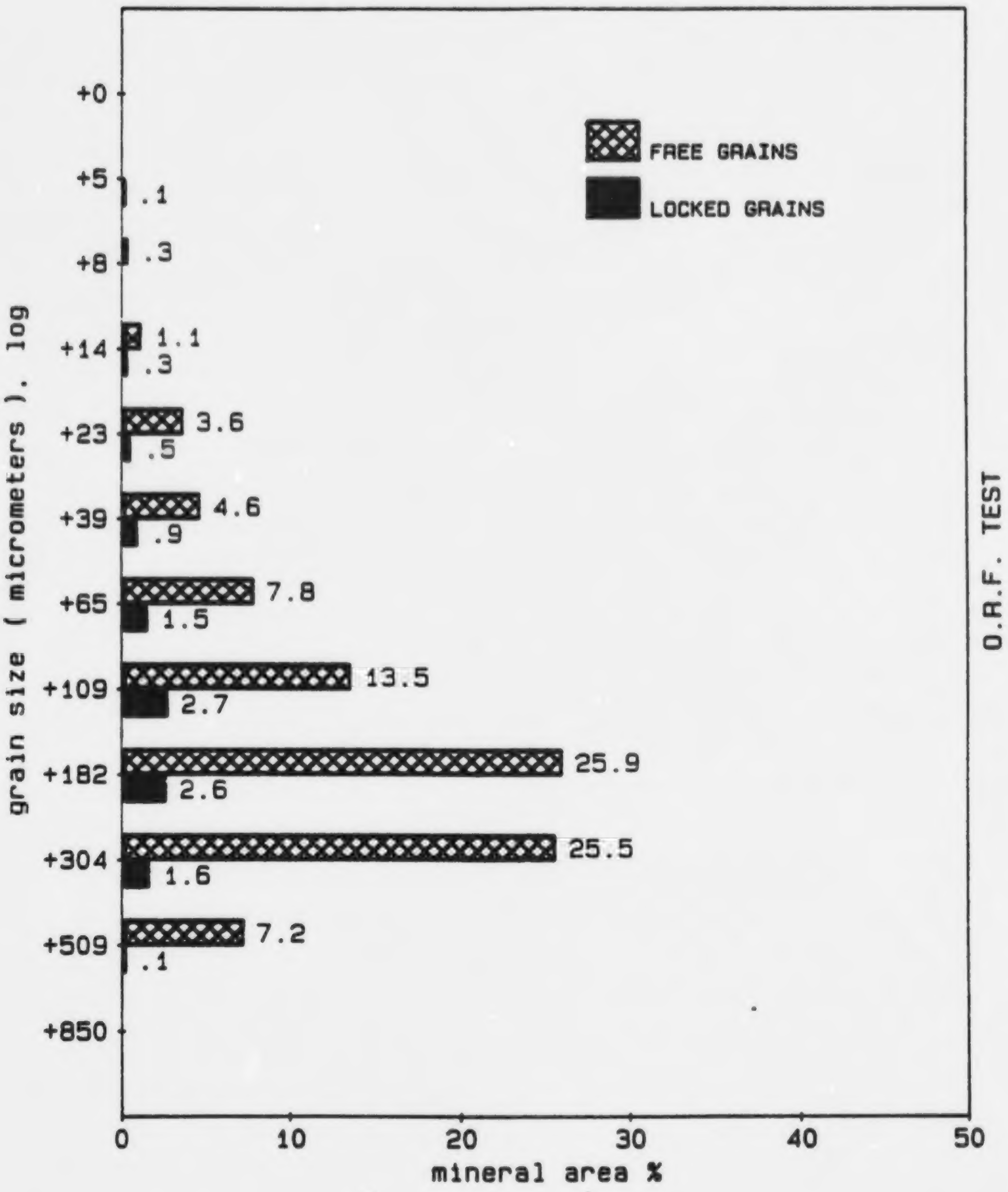
ORF Test
Hematite and Magnetite

Mill Product -20 mesh
Mill Product -28 mesh
Middlings Concentrate Tailings

Grain Size Distribution
Combined Fractions

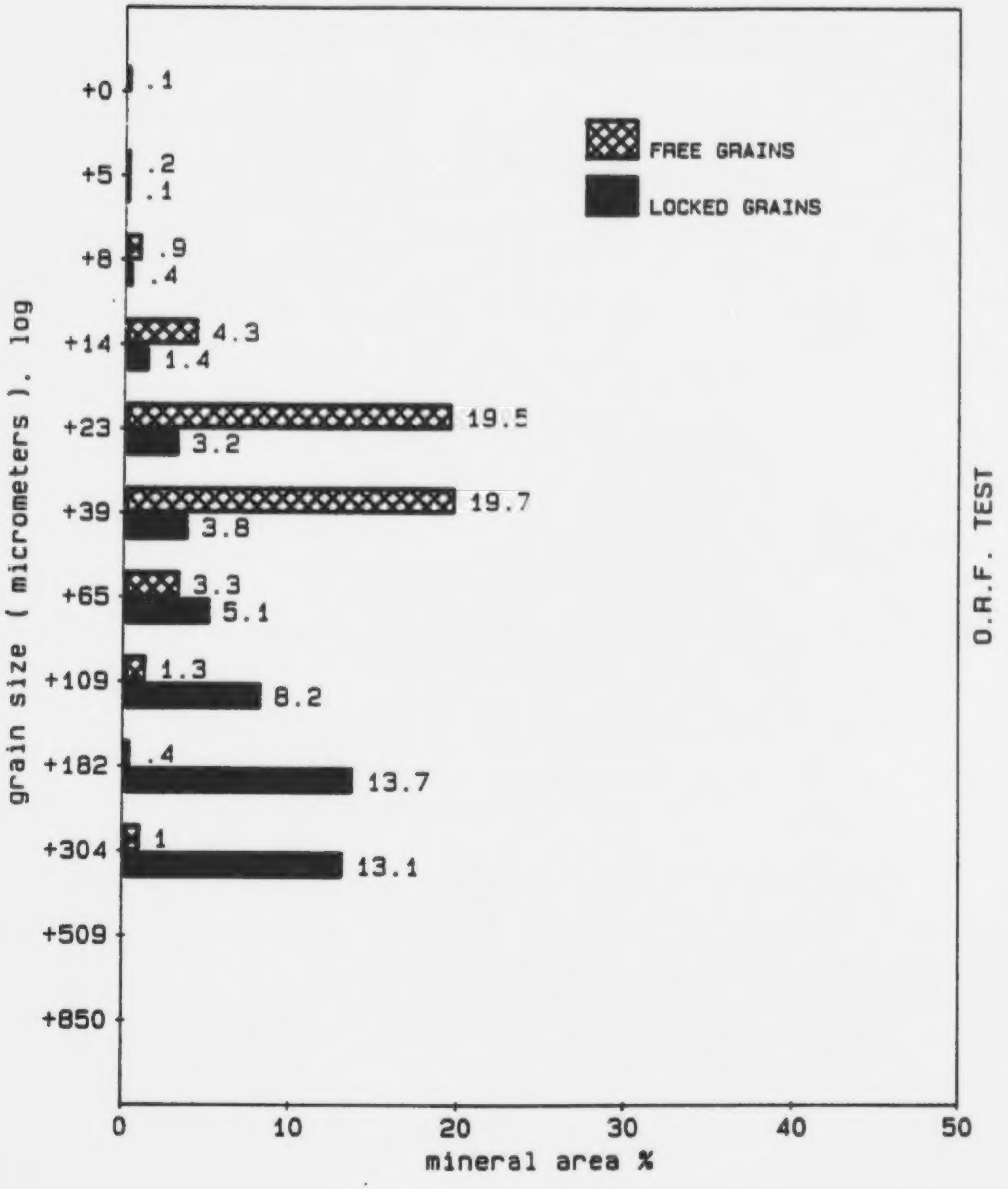
MILL PRODUCT -20 MESH
HEMATITE AND MAGNETITE
SIZE OF FREE AND LOCKED GRAINS





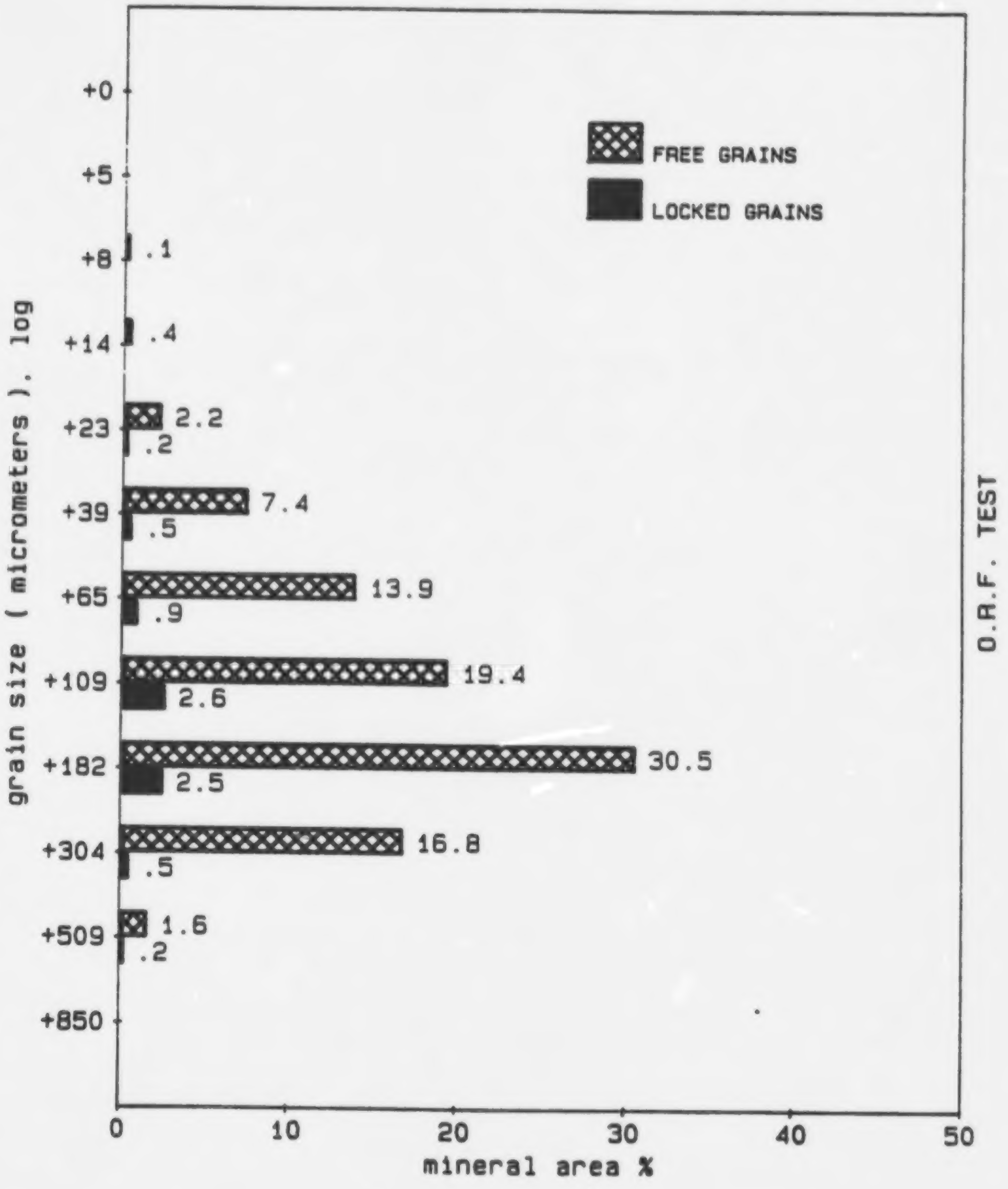
MILL PRODUCT -28 MESH
HEMATITE AND MAGNETITE
SIZE OF FREE AND LOCKED GRAINS

MIDDLINGS
HEMATITE AND MAGNETITE
SIZE OF FREE AND LOCKED GRAINS



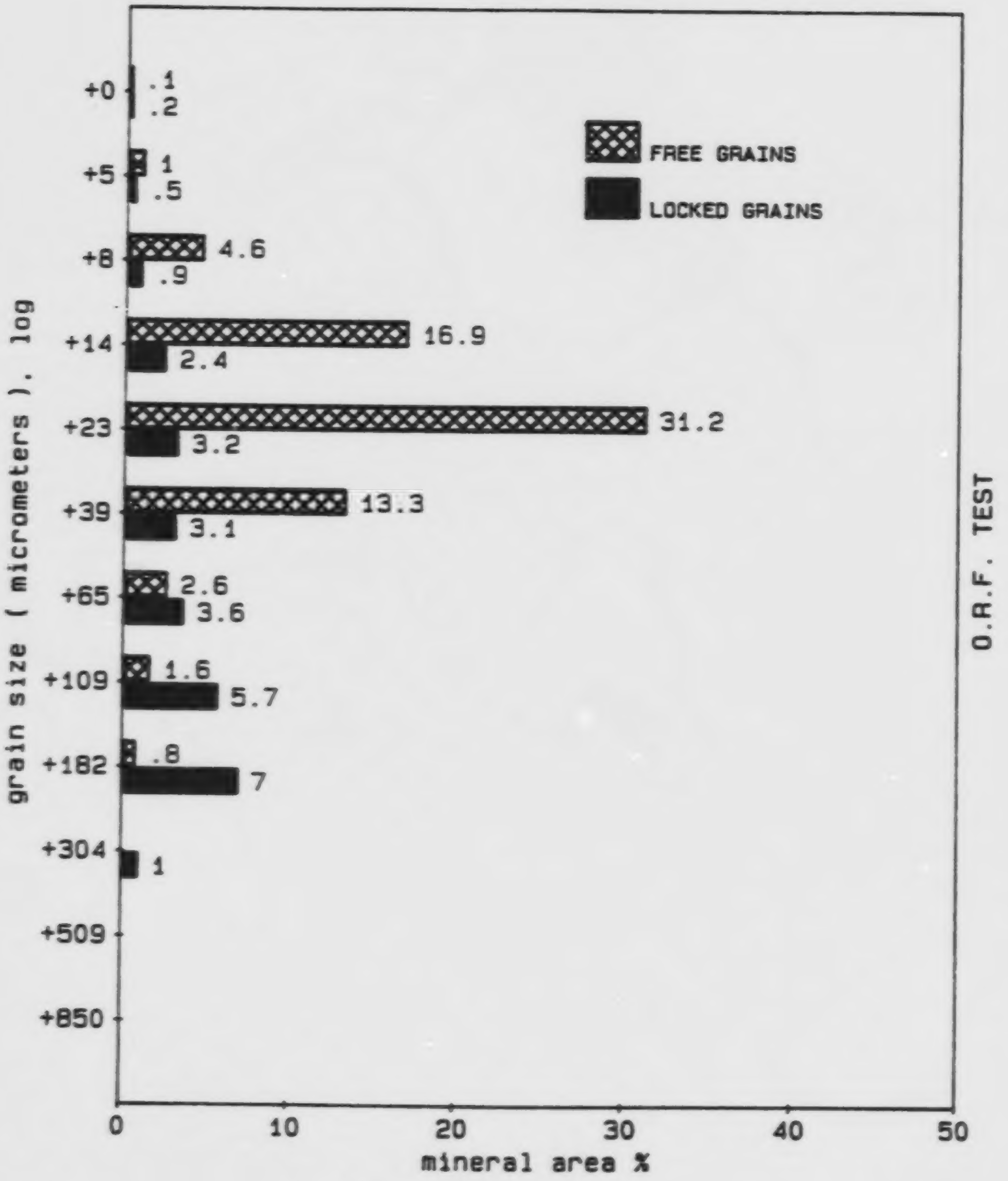
CONCENTRATE

HEMATITE AND MAGNETITE
SIZE OF FREE AND LOCKED GRAINS



TAILINGS

HEMATITE AND MAGNETITE
SIZE OF FREE AND LOCKED GRAINS



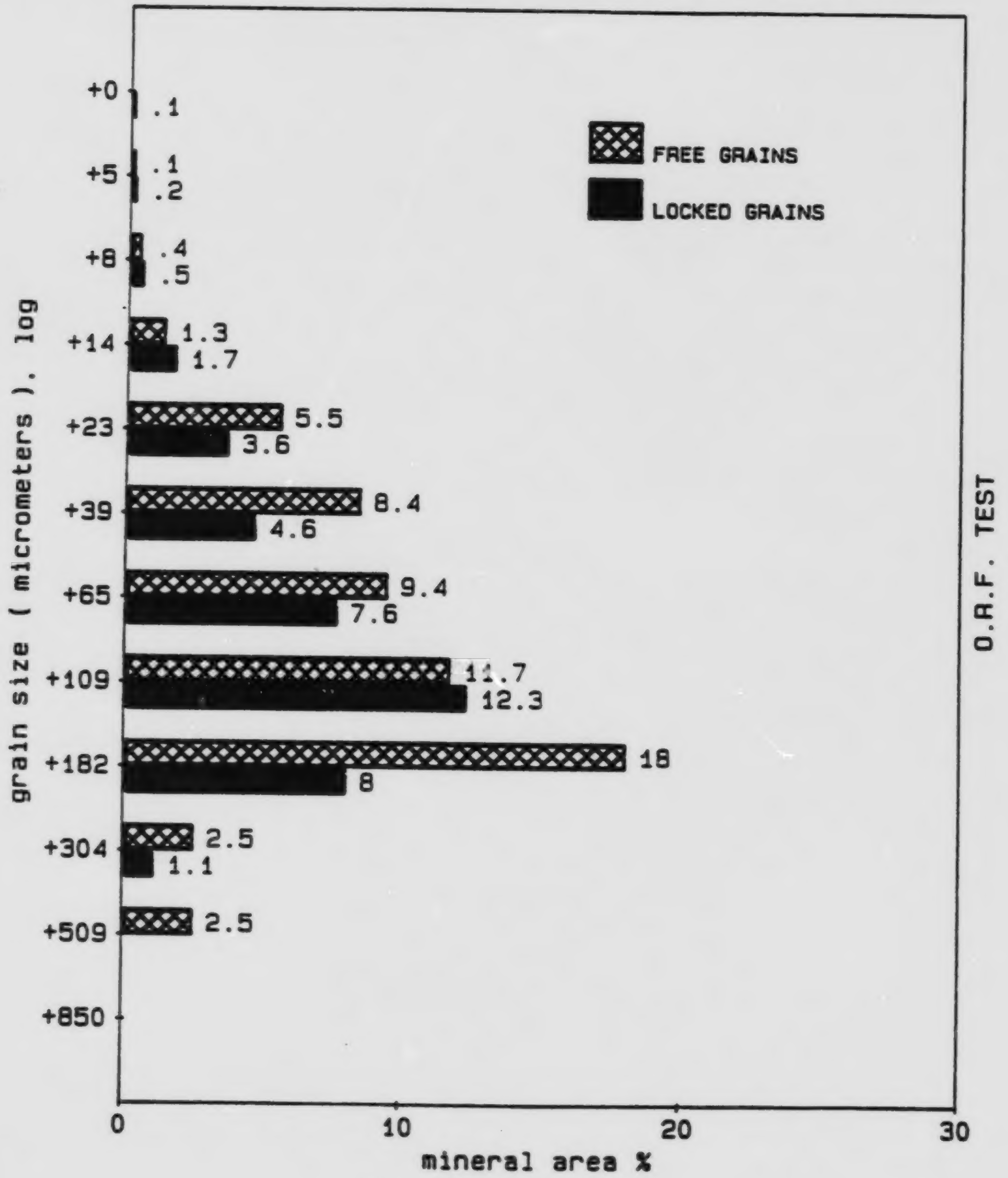
APPENDIX D-2

ORF Test
Manganese Minerals and Manganese Goethite

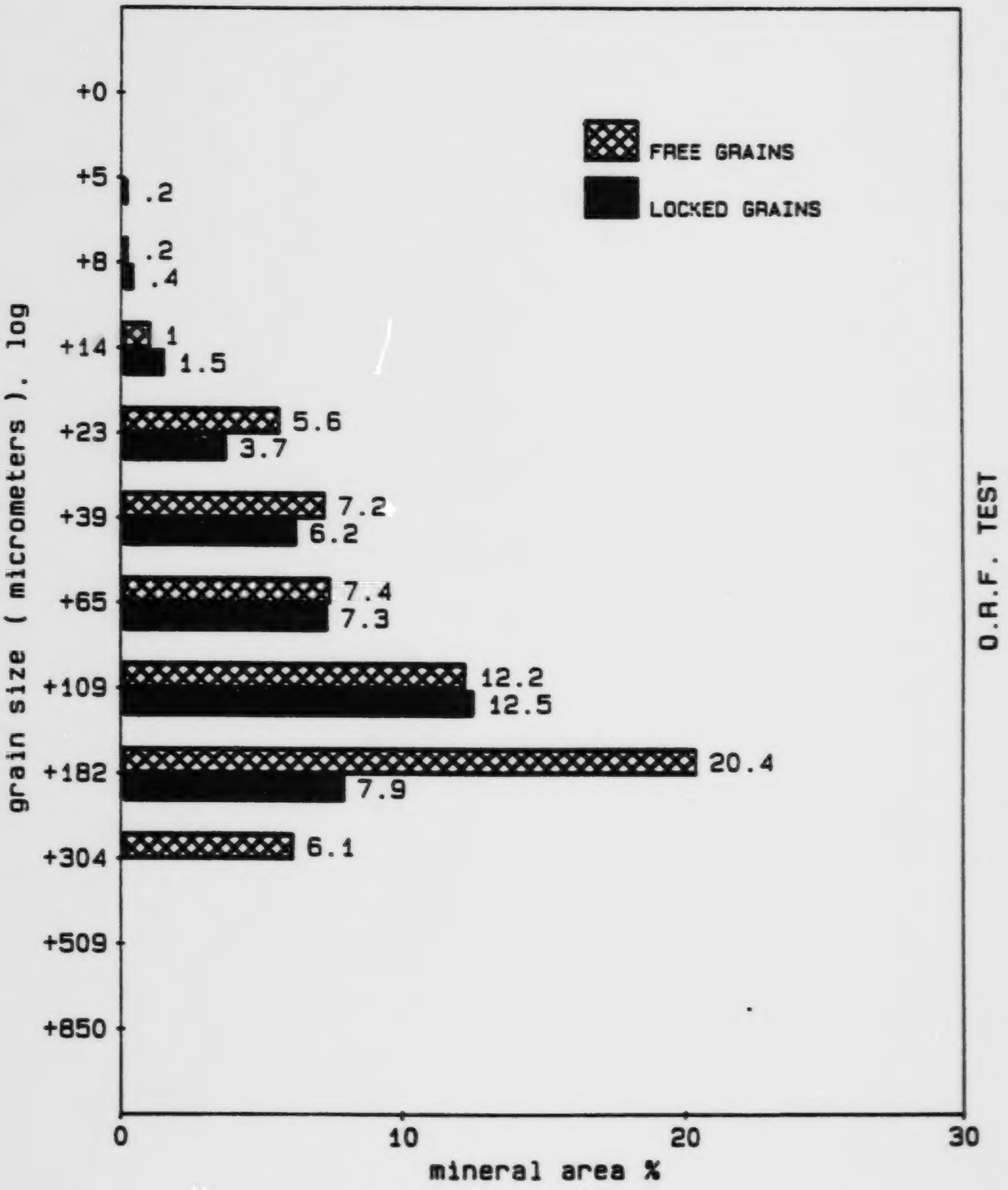
Mill Product -20 mesh
Mill Product -28 mesh
Middlings Concentrate Tailings

Grain Size Distribution
Combined Fractions

MILL PRODUCT -20 MESH
Mn MINERALS AND Mn GOETHITE
SIZE OF FREE AND LOCKED GRAINS

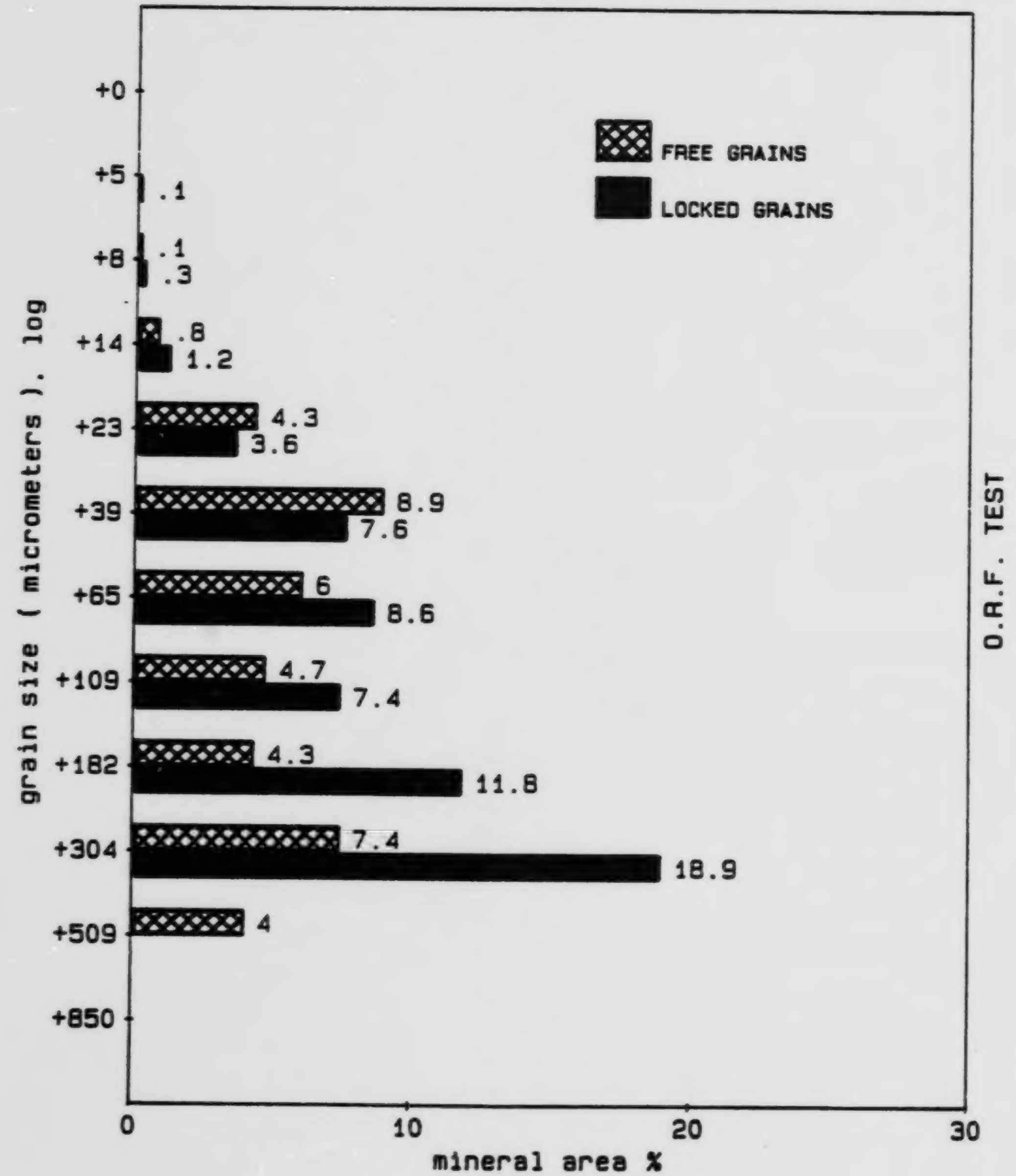


MILL PRODUCT -28 MESH
Mn MINERALS AND Mn GOETHITE
SIZE OF FREE AND LOCKED GRAINS

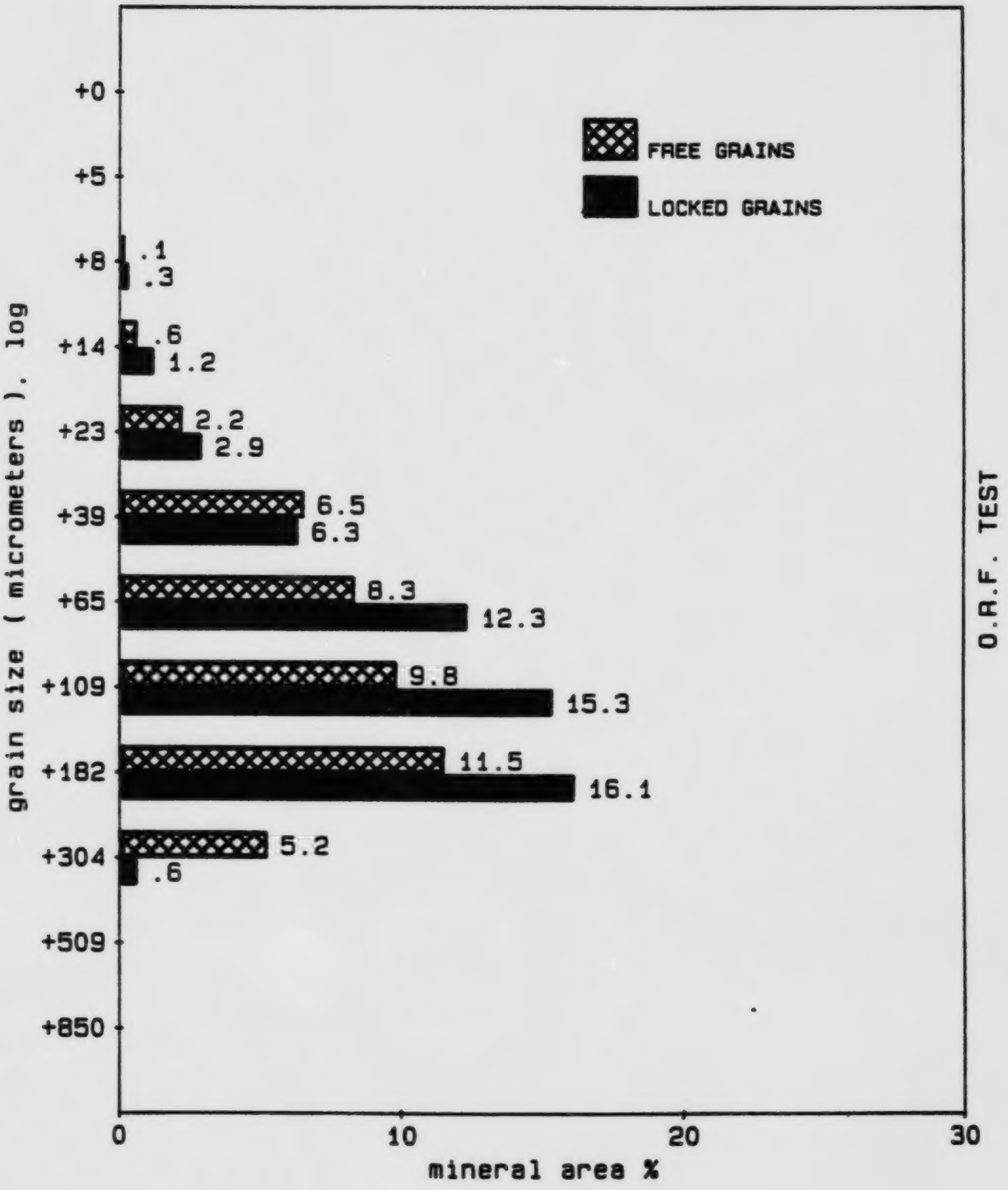


MIDDLINGS

Mn MINERALS AND Mn GOETHITE
SIZE OF FREE AND LOCKED GRAINS

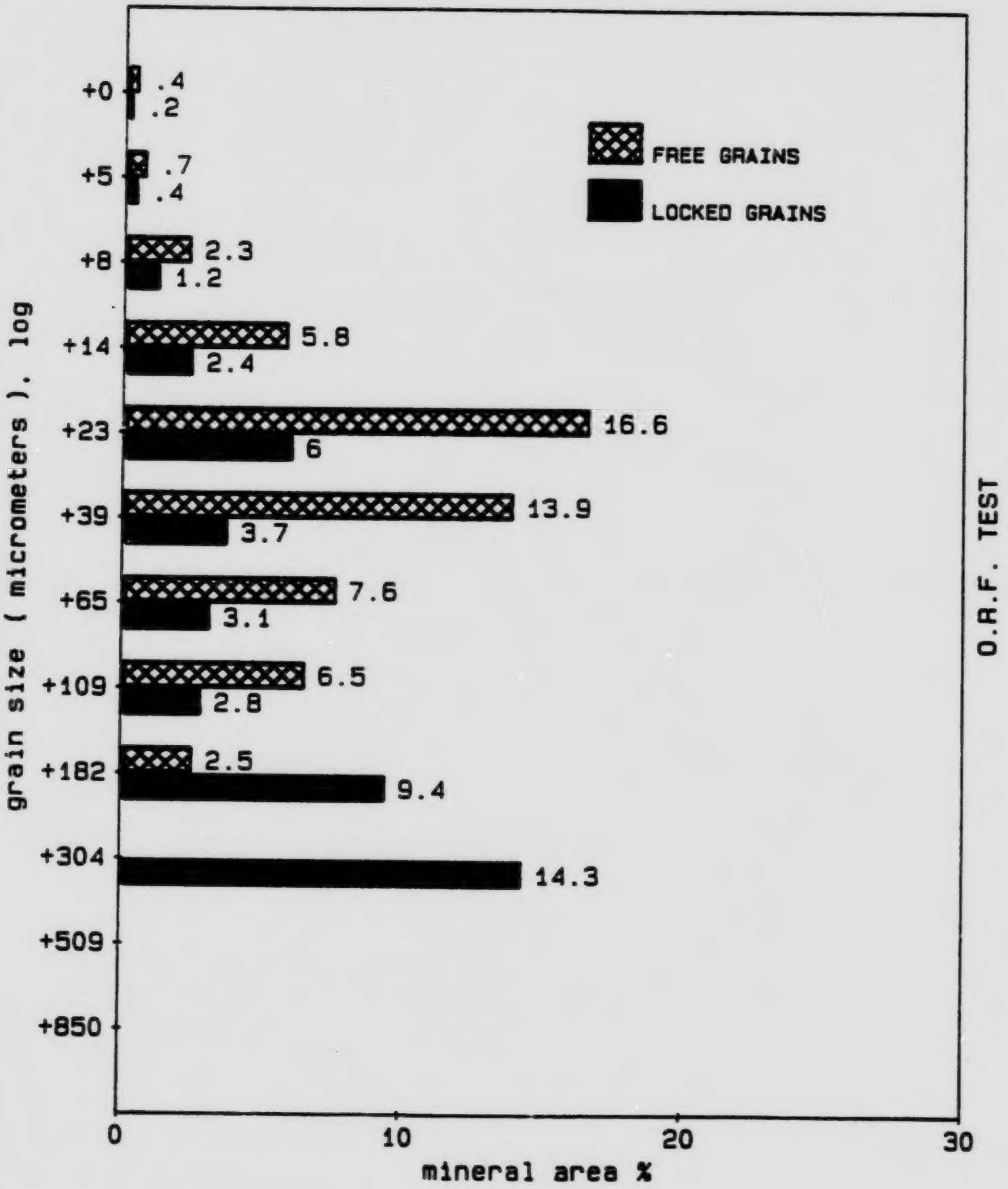


CONCENTRATE
Mn MINERALS AND Mn GOETHITE
SIZE OF FREE AND LOCKED GRAINS



TAILINGS

Mn MINERALS AND Mn GOETHITE
SIZE OF FREE AND LOCKED GRAINS



APPENDIX D-3

ORF Test
Goethite Free of Manganese

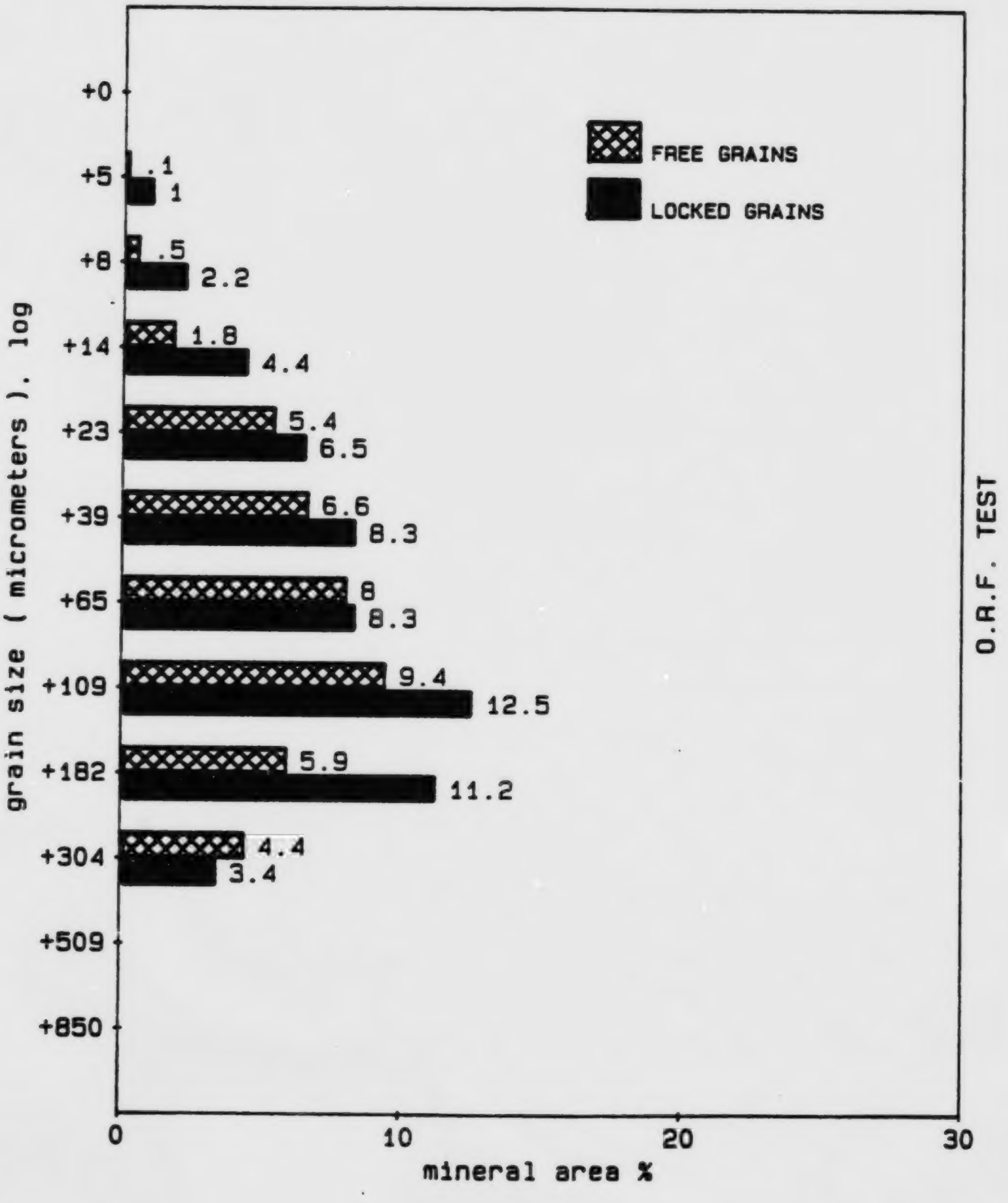
Mill Product -20 mesh
Mill Product -28 mesh
Middlings Concentrate Tailings

Grain Size Distribution
Combined Fractions

MILL PRODUCT -20 MESH

GOETHITE FREE OF Mn

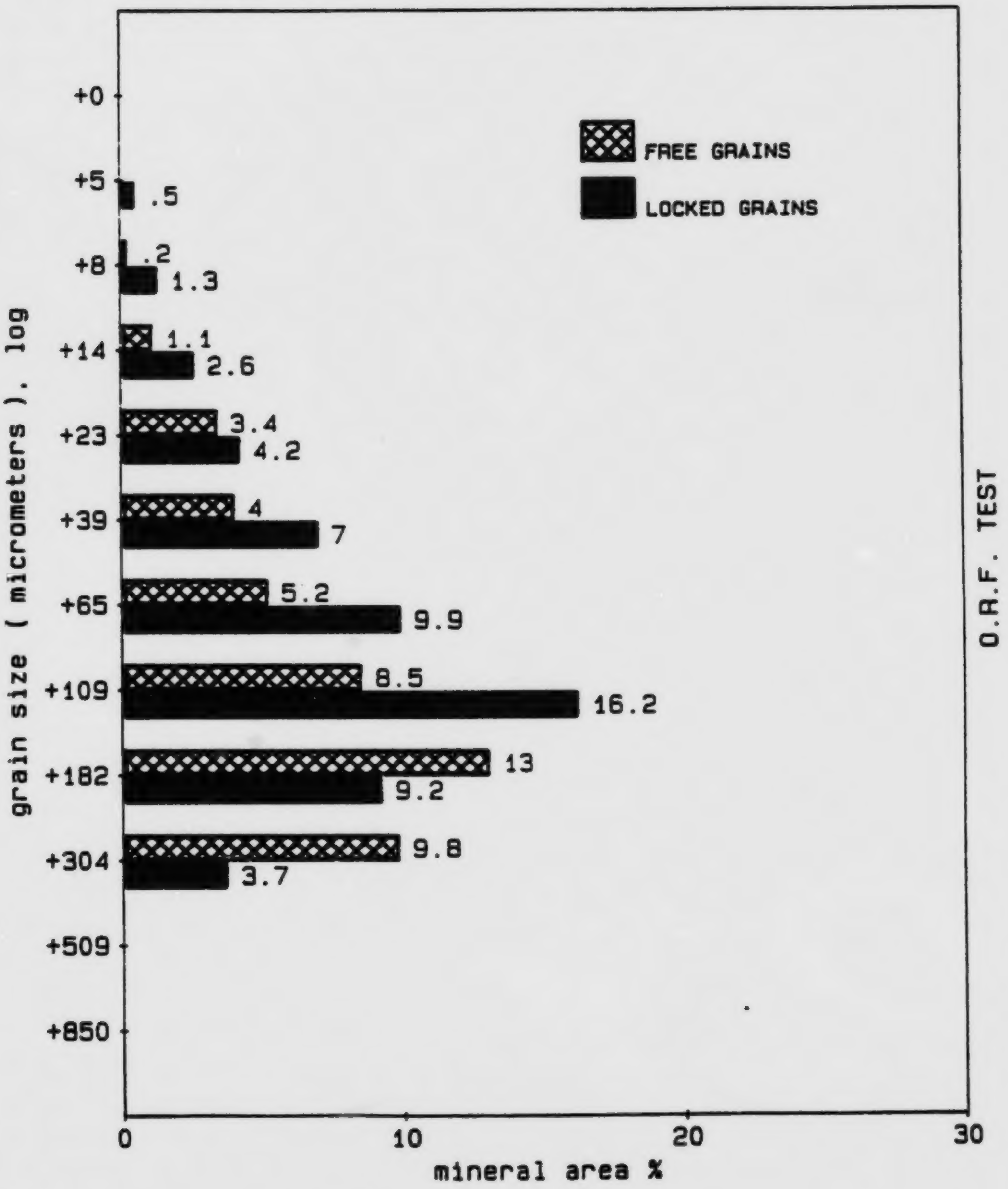
SIZE OF FREE AND LOCKED GRAINS

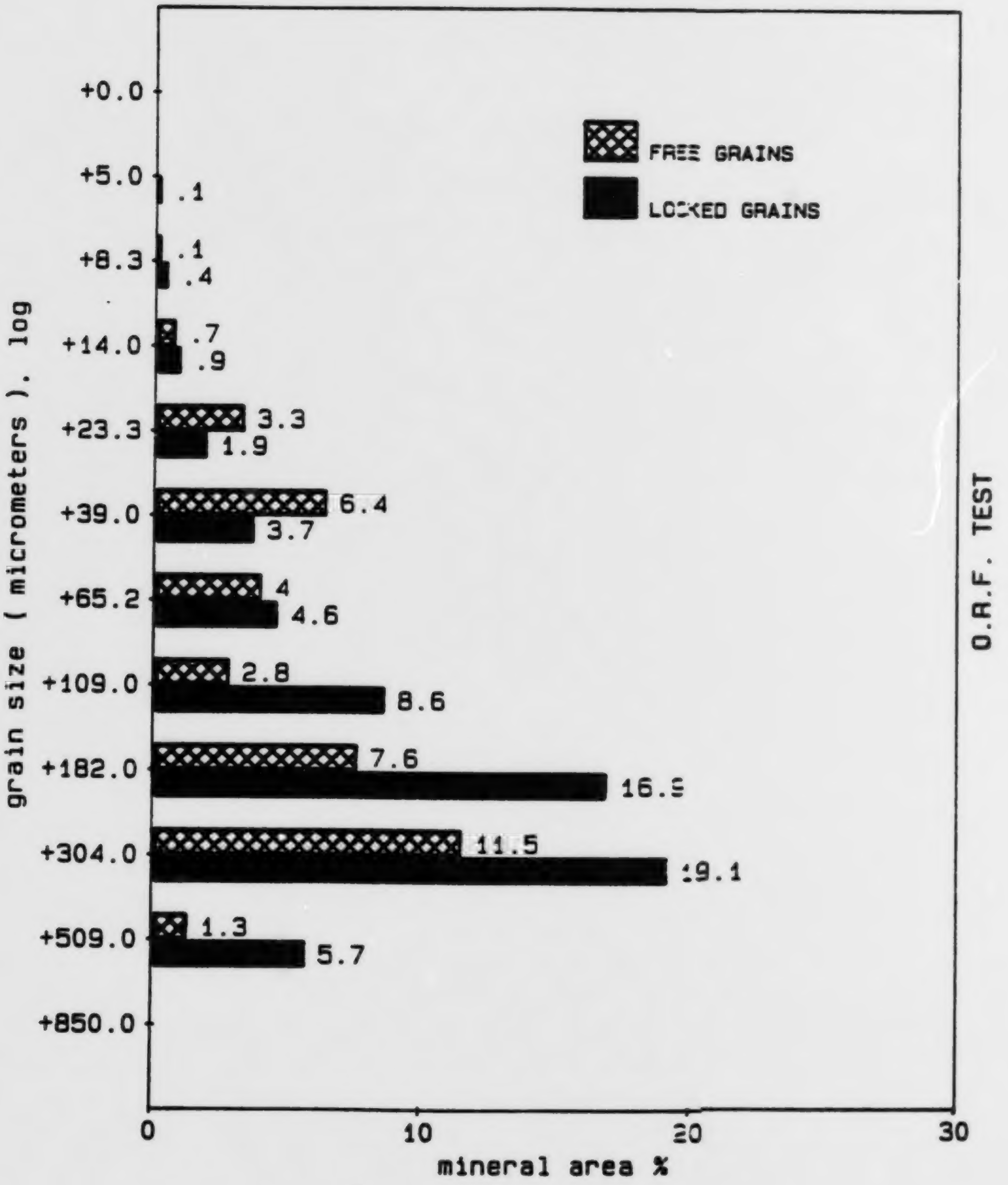


MILL PRODUCT -28 MESH

GOETHITE FREE OF Mn

SIZE OF FREE AND LOCKED GRAINS



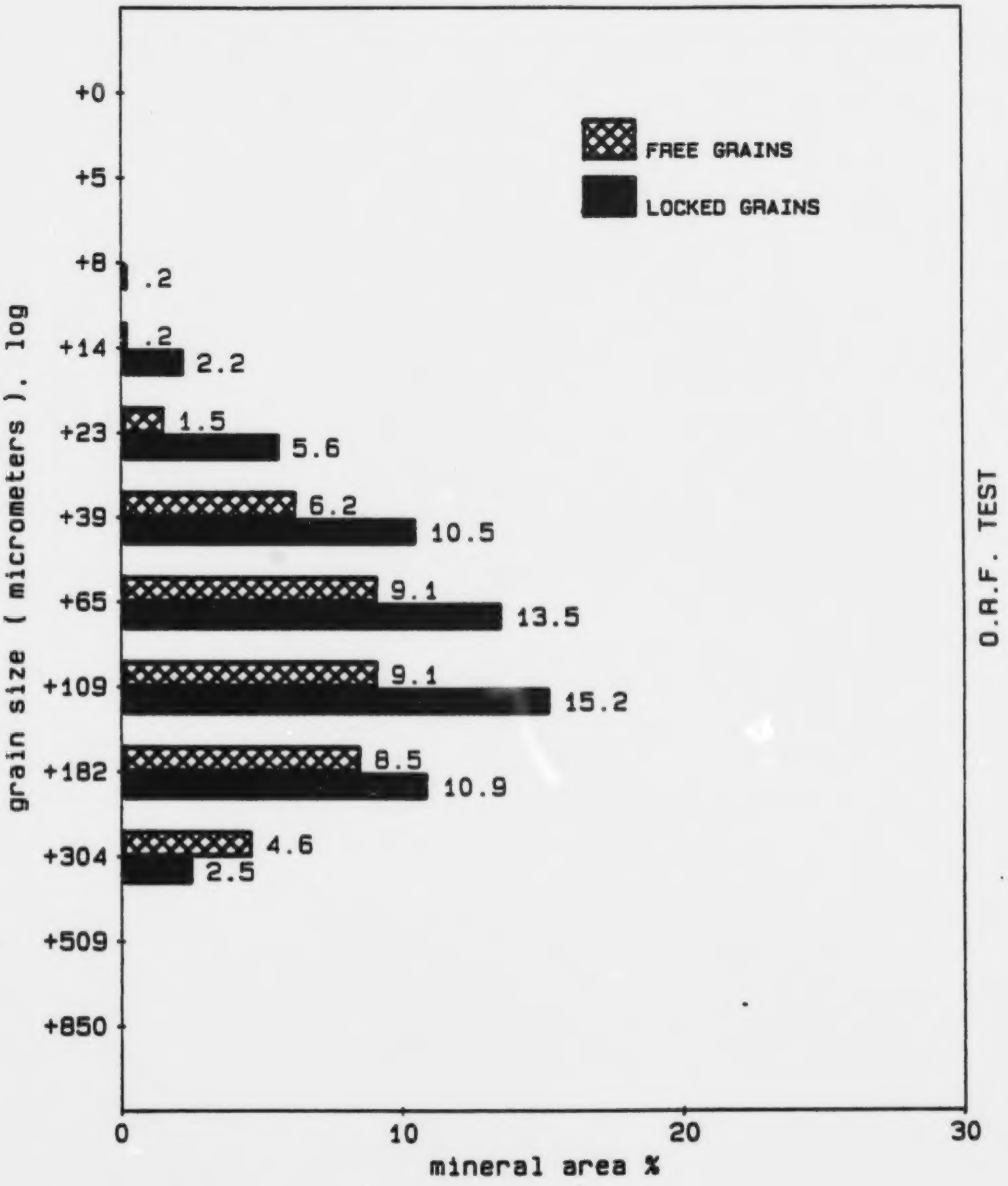


MIDDLINGS
GOETHITE FREE OF Mn
SIZE OF FREE AND LOCKED GRAINS

CONCENTRATE

GOETHITE FREE OF Mn

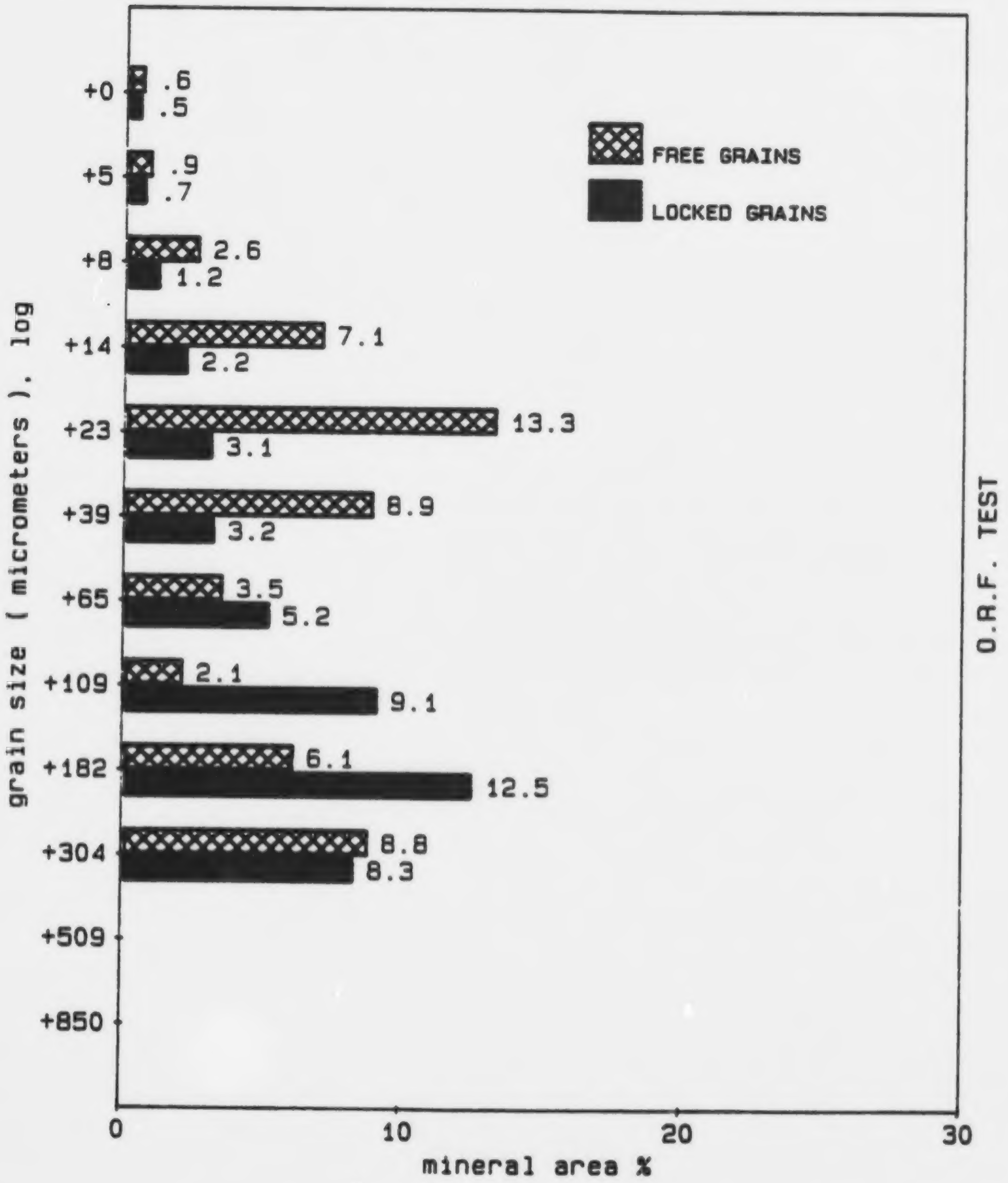
SIZE OF FREE AND LOCKED GRAINS



TAILINGS

GOETHITE FREE OF Mn

SIZE OF FREE AND LOCKED GRAINS



APPENDIX D-4

ORF Test
Silicates

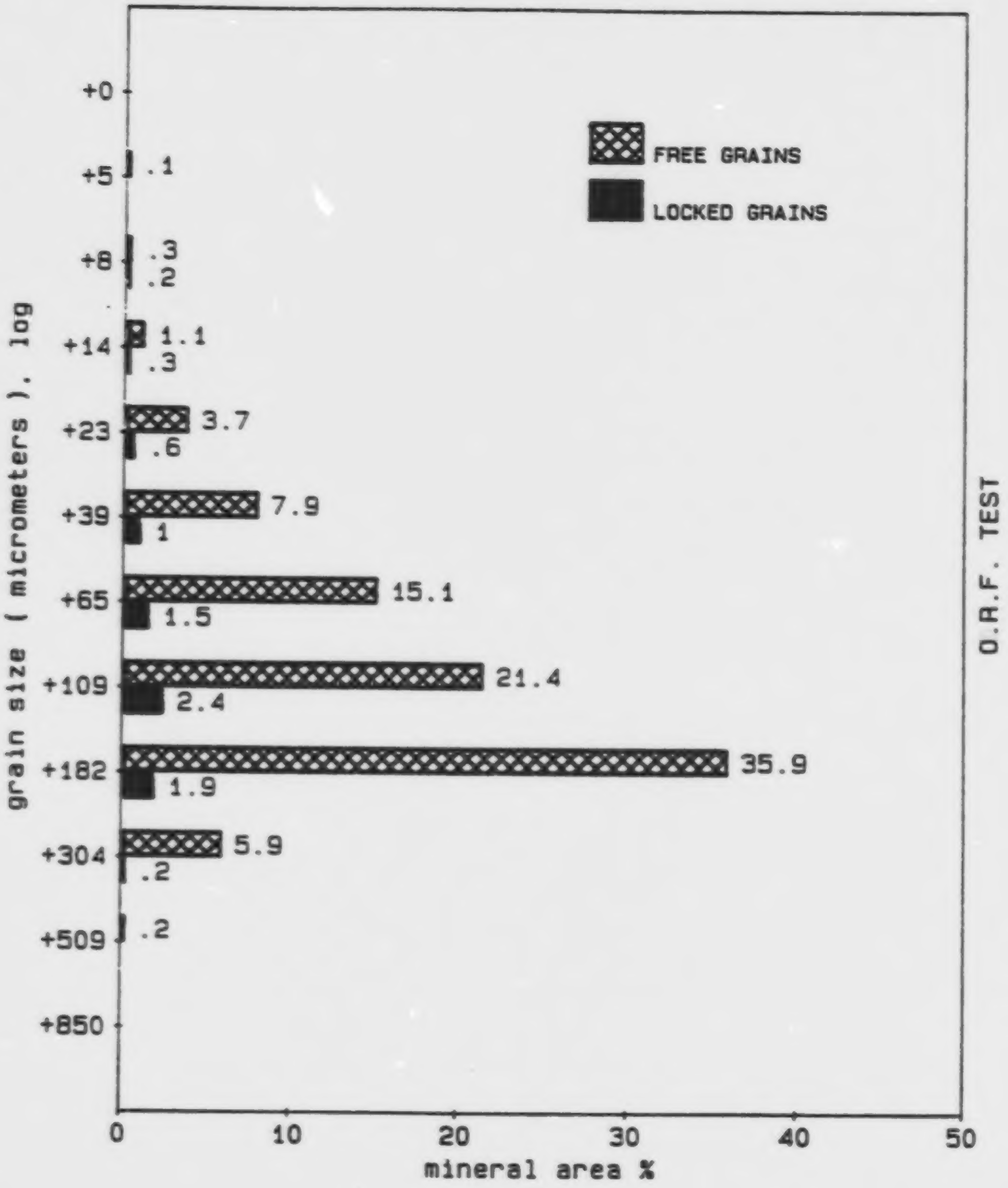
Mill Product -20 mesh
Mill Product -28 mesh
Middlings Concentrate Tailings

Grain Size Distribution
Combined Fractions

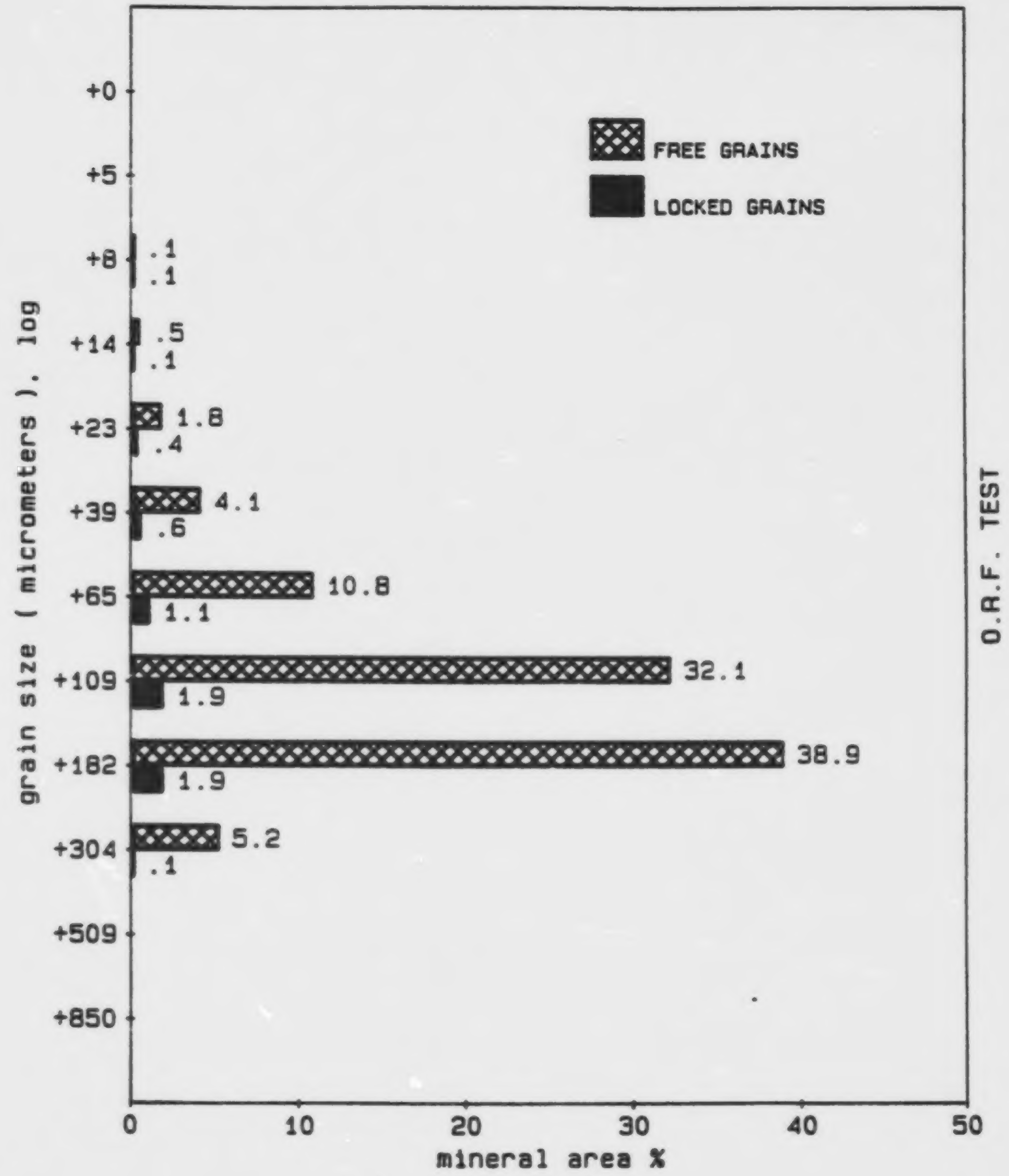
MILL PRODUCT -20 MESH

SILICATES

SIZE OF FREE AND LOCKED GRAINS



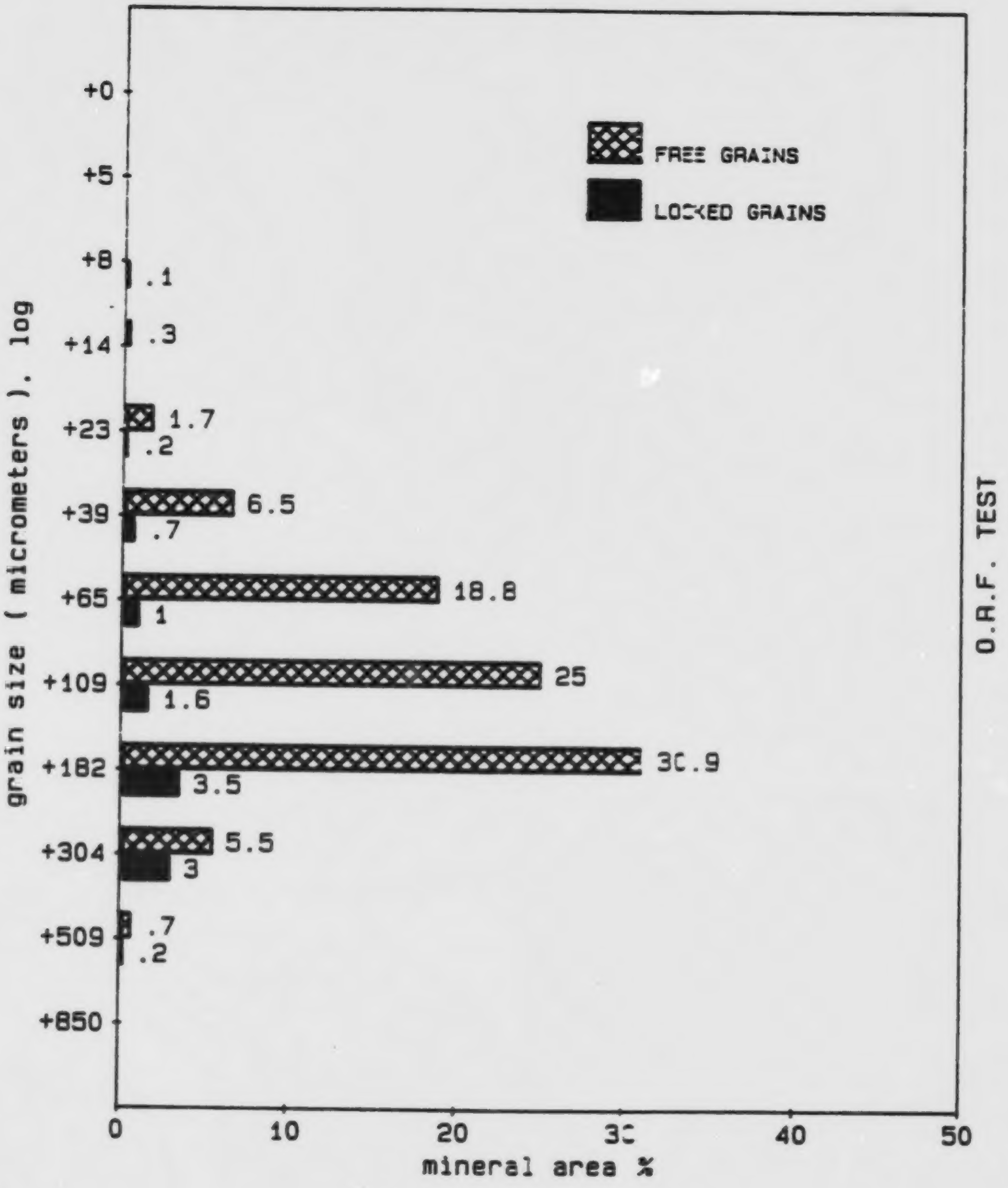
MILL PRODUCT -28 MESH
SILICATES
SIZE OF FREE AND LOCKED GRAINS



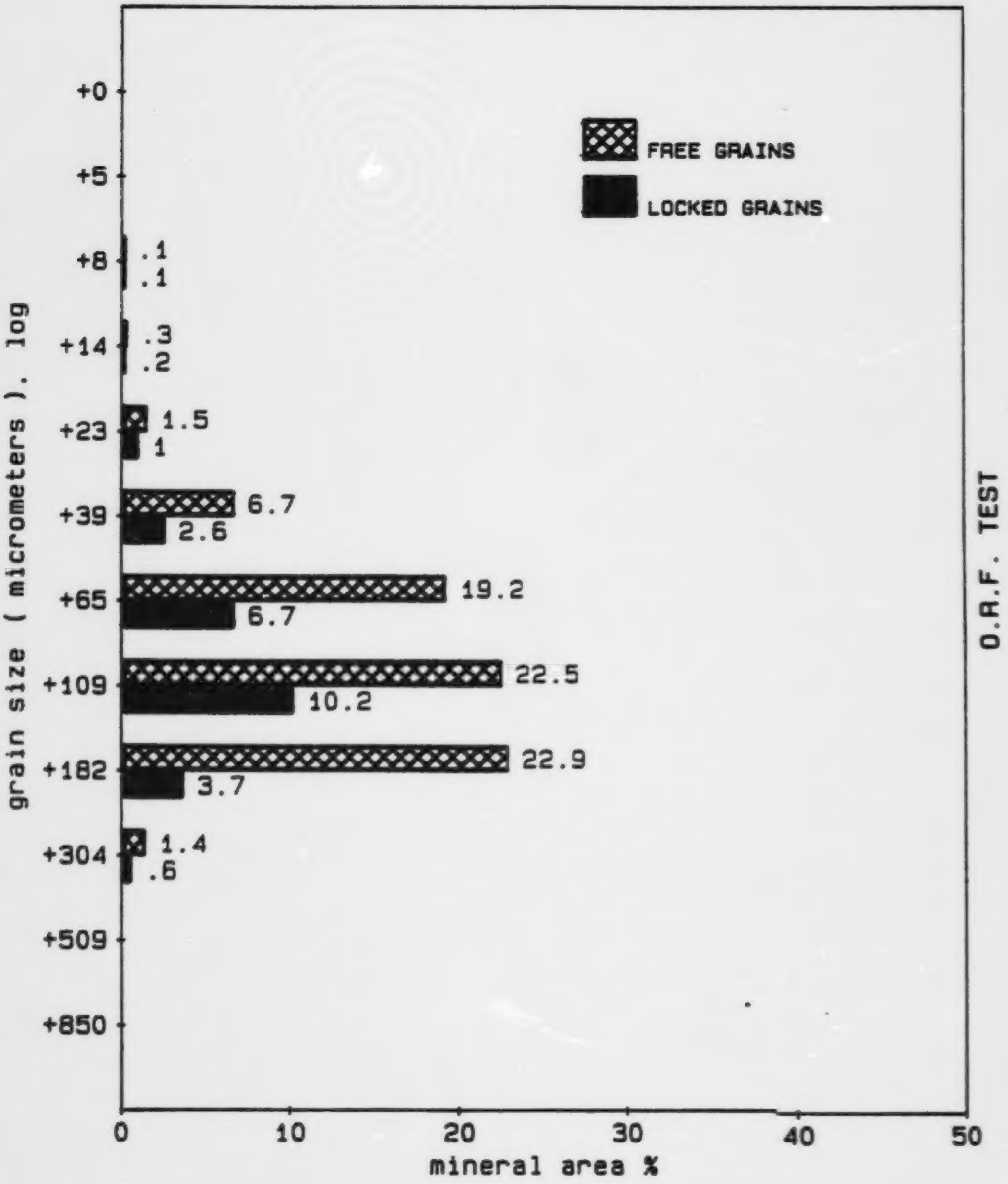
MIDDLINGS

SILICATES

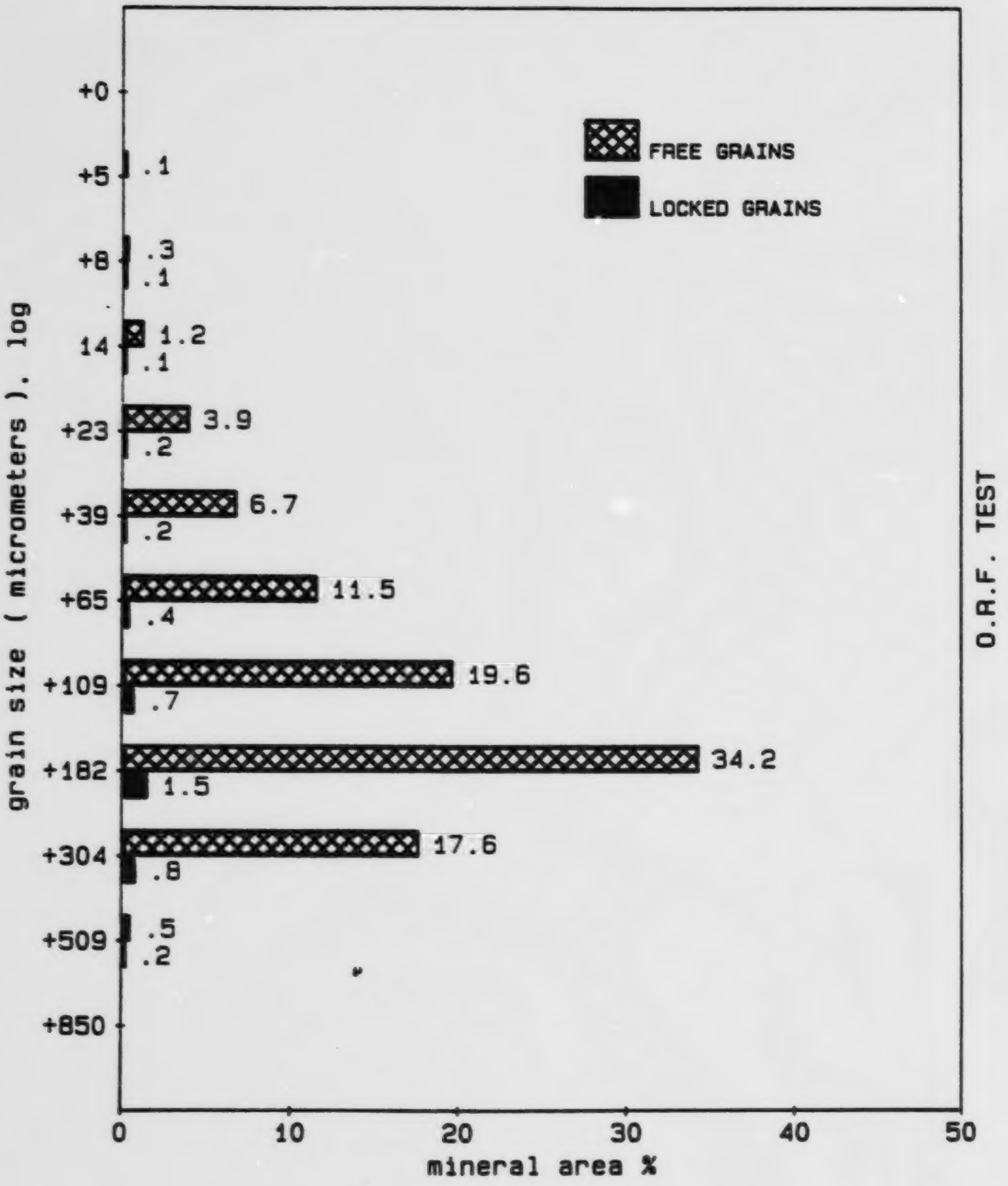
SIZE OF FREE AND LOCKED GRAINS



CONCENTRATE
SILICATES
SIZE OF FREE AND LOCKED GRAINS



TAILINGS
SILICATES
SIZE OF FREE AND LOCKED GRAINS



APPENDIX E-1

Scully Concentrator, Combined Fractions
All Mineral Phases
Distribution of Locked Grains Finer Than
65 mic. (Approx. -200 mesh)
All Samples

SCULLY CONCENTRATOR

CONTENT OF LOCKED GRAINS FINER THEN -65 MIC. (APPROX. -200 MESH)
ALL MINERAL PHASES

COMBINED FRACTIONS

SAMPLE	MINERAL PHASE			
	A	B	C	D
trommel screen undersize	1.7	13.8	6.5	1.4
sizing screen oversize	0.8	4.1	2.7	0.6
sizing screen undersize	1.6	14.2	7.5	0.9
rougher spiral middlings	1.3	4.5	3.3	0.8
rougher spiral concentrate	0.5	5.9	6.5	0.7
rougher spiral tailings	10.8	20.9	20.0	1.2
cleaner spiral concentrate	0.7	4.4	19.2	2.6
cleaner spiral tailings	4.2	7.0	7.8	0.6

* reported as weight % of mineral pnase in sample

LEGEND

A : HEMATITE AND MAGNETITE
B : Mn MINERALS AND Mn GOETHITE
C : GOETHITE FREE OF Mn
D : SILICATES

APPENDIX E-2

ORF Test Combined Fractions
All Mineral Phases
Distribution of Locked Grains Finer Than
65 mic. (Approx. -200 mesh)
All Samples

ORF TEST

CONTENT OF LOCKED GRAINS FINER THEN -65 MIC. (APPROX. -200 MESH)
ALL MINERAL PHASES

COMBINED FRACTIONS

SAMPLE	MINERAL PHASE			
	A	B	C	D
mill product -20 Mesh	2.8	10.7	22.4	2.1
mill product -28 Mesh	1.8	12.0	15.6	1.2
middlings	10.5	12.8	7.0	1.0
concentrate	0.7	10.7	18.5	3.9
tailings	10.3	13.9	10.9	0.6

* reported as weight % of mineral phase in sample

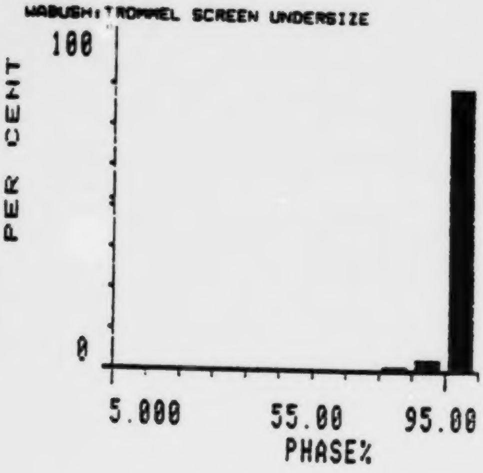
LEGEND

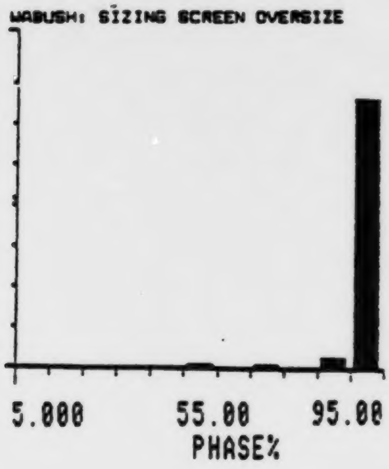
A : HEMATITE AND MAGNETITE
B : Mn MINERALS AND Mn GOETHITE
C : GOETHITE FREE OF Mn
D : SILICATES

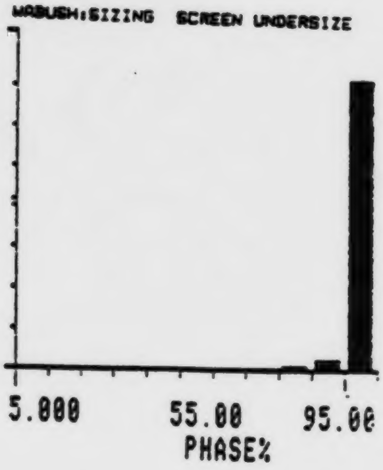
APPENDIX F

Scully Concentrator,
All Mineral Phases
Classes of Liberation,
Combined Fractions

LIBERATION OF MAGNETITE AND HEMATITE


WABUSH:TROMMEL SCREEN UNDERSIZE


WABUSH: SIZING SCREEN OVERSIZE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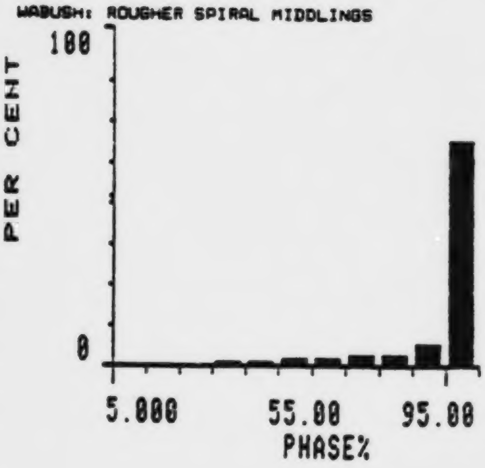
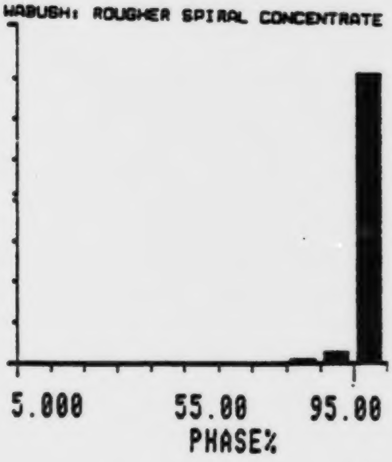
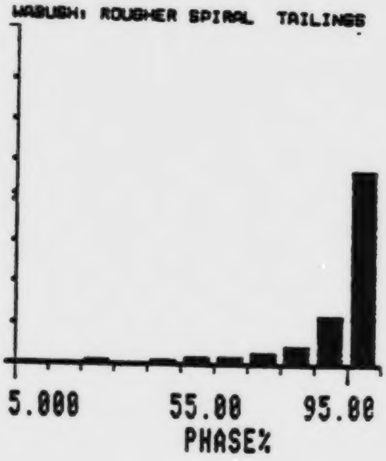
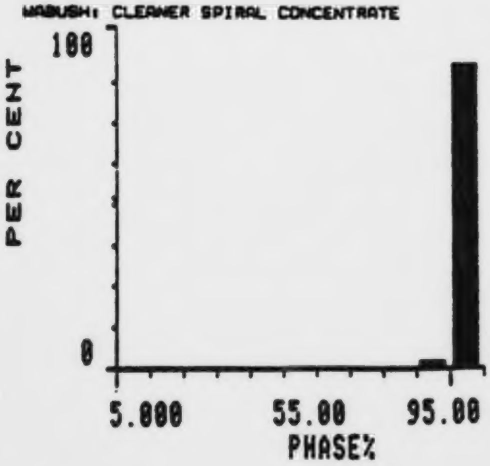
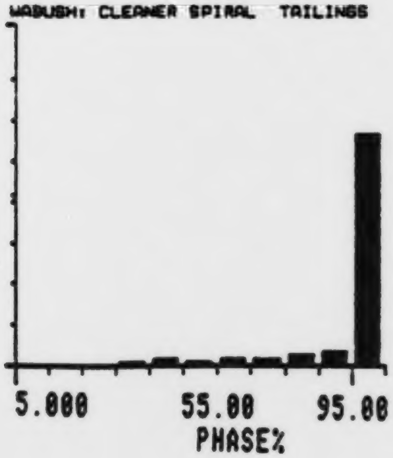

WABUSH: ROUGHER SPIRAL MIDDLINGS


WABUSH: ROUGHER SPIRAL CONCENTRATE


WABUSH: ROUGHER SPIRAL TAILINGS


WABUSH: CLEANER SPIRAL CONCENTRATE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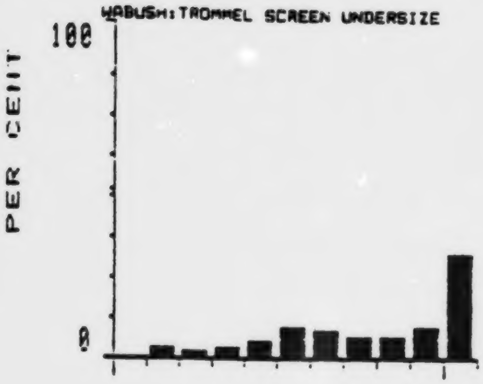
LIBERATION OF MANGANESE MINERALS+MN-RICH GOETHITE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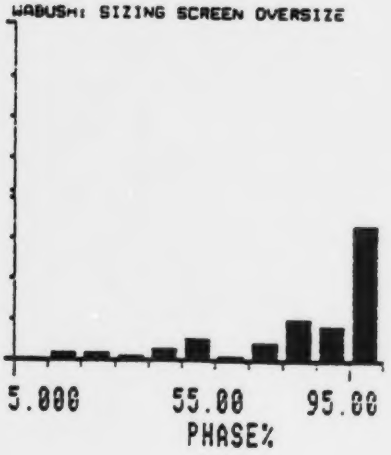
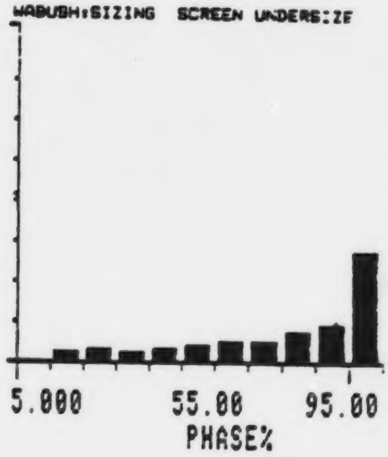
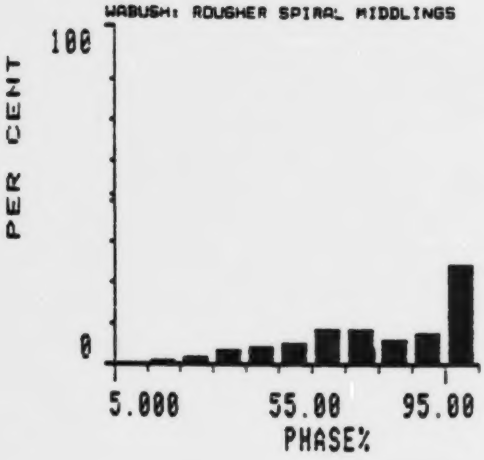
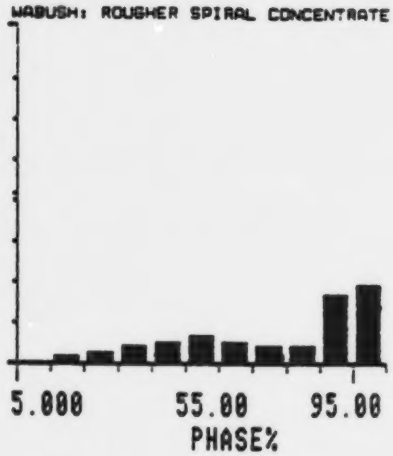
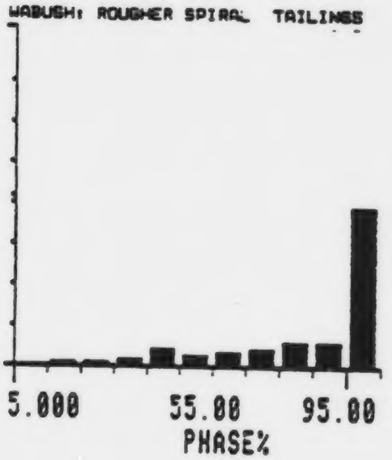
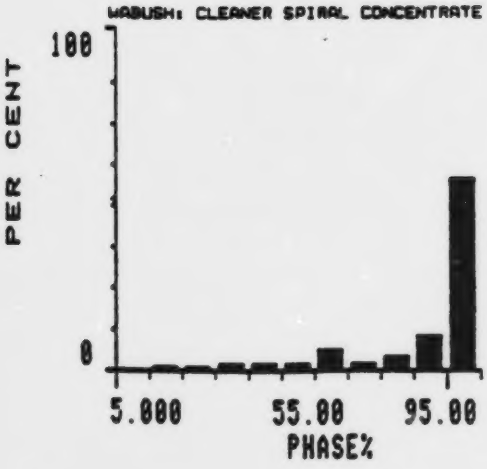

WABUSH: SIZING SCREEN OVERSIZE

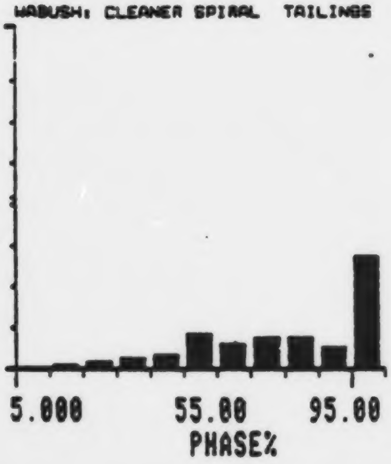

WABUSH:SIZING SCREEN UNDERSIZE


WABUSH: ROUGHER SPIRAL MIDDLINGS


WABUSH: ROUGHER SPIRAL CONCENTRATE

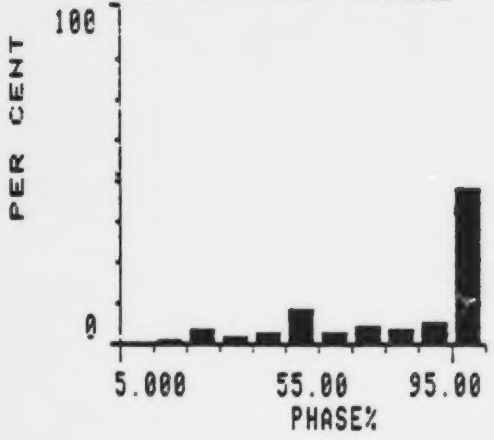

WABUSH: ROUGHER SPIRAL TAILINGS


WABUSH: CLEANER SPIRAL CONCENTRATE

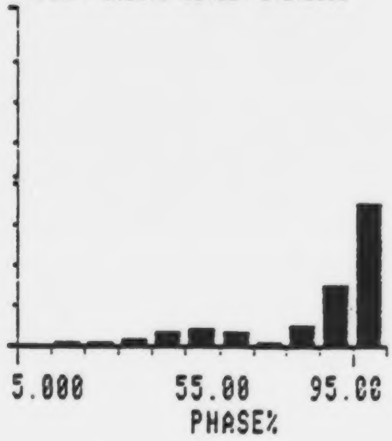

WABUSH: CLEANER SPIRAL TAILINGS

LIBERATION OF GOETHITE

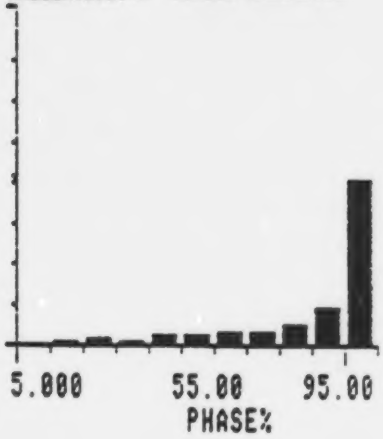
WABUSH:TROMMEL SCREEN UNDERSIZE



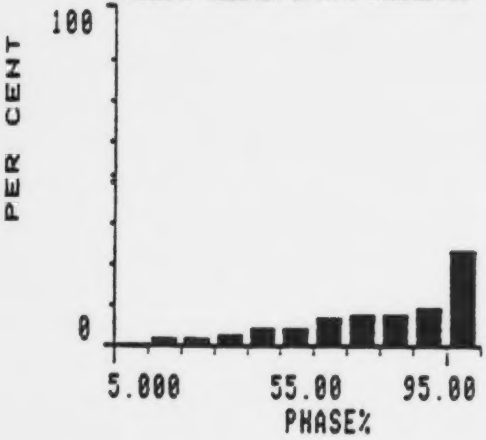
WABUSH: SIZING SCREEN OVERSIZE



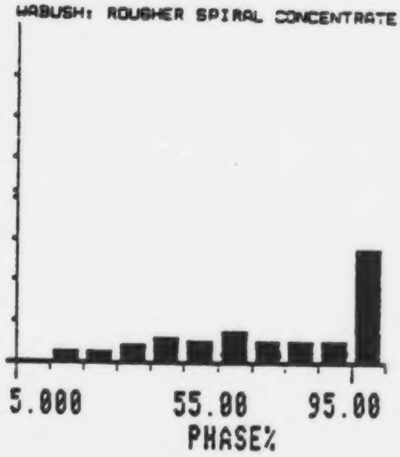
WABUSH:SIZING SCREEN UNDERSIZE



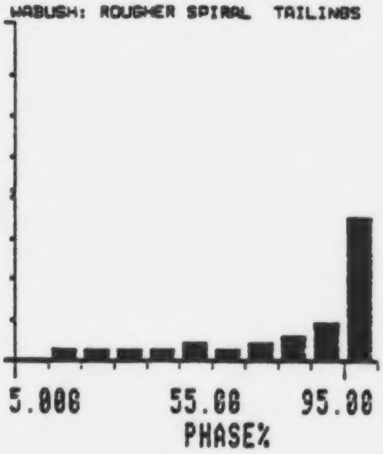
WABUSH: ROUGHER SPIRAL MIDDLINGS



WABUSH: ROUGHER SPIRAL CONCENTRATE



WABUSH: ROUGHER SPIRAL TAILINGS



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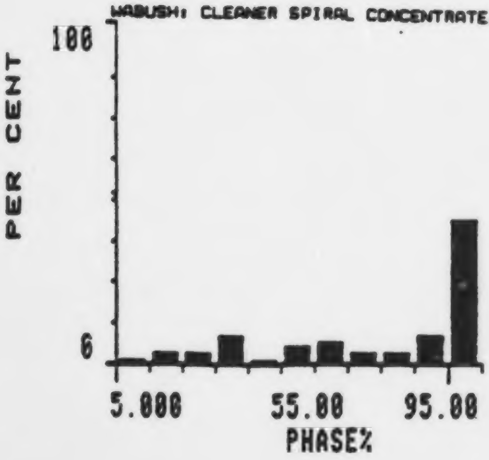
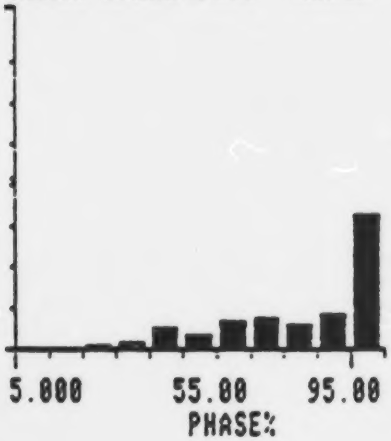
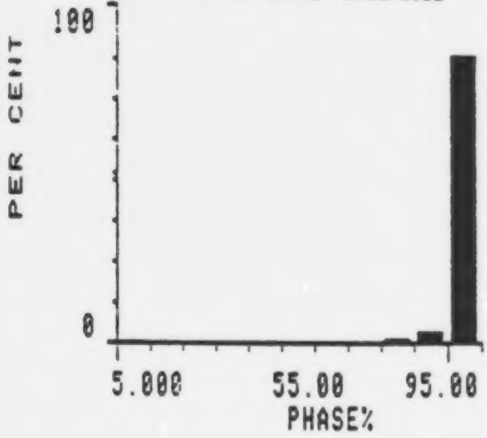


WABUSH: CLEANER SPIRAL TAILINGS

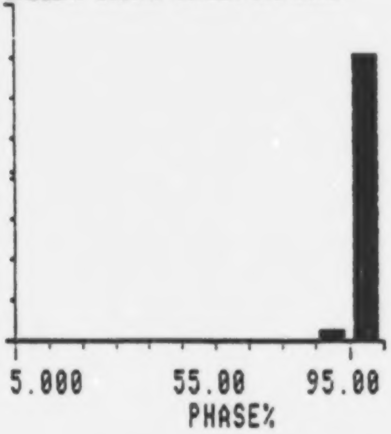


LIBERATION OF SILICATES

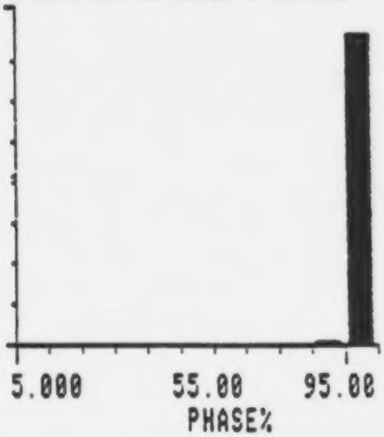
WABUSH:TROMMEL SCREEN UNDERSIZE



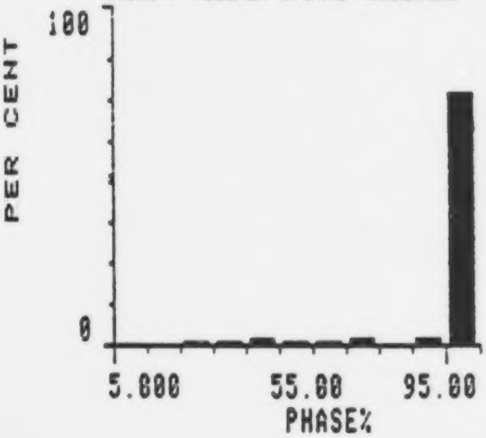
WABUSH: SIZING SCREEN OVERSIZE



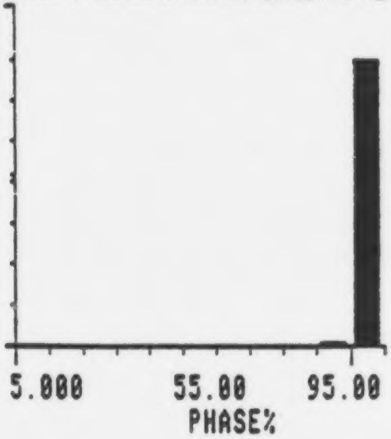
WABUSH:SIZING SCREEN UNDERSIZE



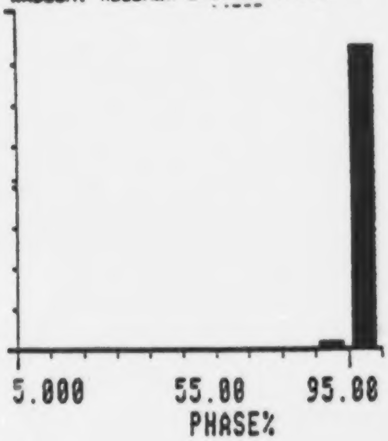
WABUSH: ROUGHER SPIRAL MIDDLINGS



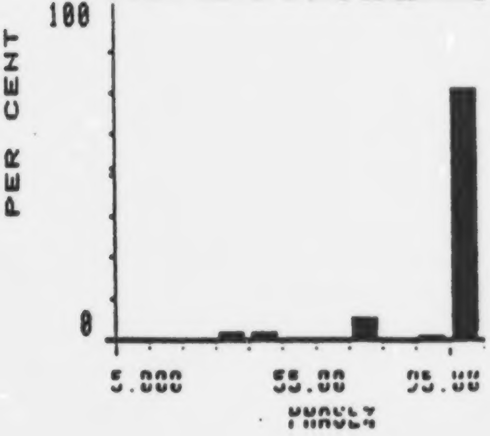
WABUSH: ROUGHER SPIRAL CONCENTRATE.



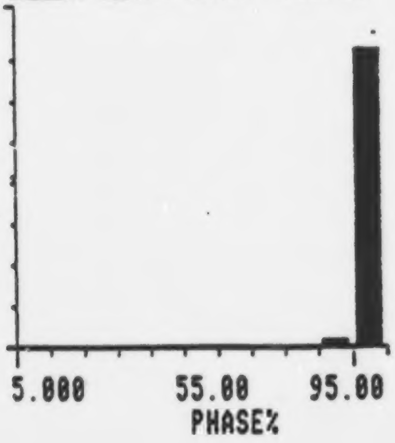
WABUSH: ROUGHER SPIRAL TAILINGS



WABUSH: CLEANER SPIRAL CONCENTRATE



WABUSH: CLEANER SPIRAL TAILINGS



APPENDIX G-1

Scully Concentrator,
All Mineral Phases
Distribution of Free Grains
Individual Sieve Fractions

SCULLY CONCENTRATOR

DISTRIBUTION OF FREE GRAINS*
HEMATITE AND MAGNETITE

INDIVIDUAL SIEVE FRACTIONS

SAMPLE	+850 mic. +20 mesh	+212 mic. +65 mesh	+106 mic. +150 mesh	+53 mic. +270 mesh	-53 mic. -270 mesh
trommel screen undersize	51.3	92.2	95.6	91.4	88.3
sizing screen oversize	73.5	96.2	86.1	86.3	98.0
sizing screen undersize	67.4	73.4	92.4	94.2	91.7
rougher spiral middlings	22.9	68.4	88.0	92.6	90.8
rougher spiral concentrate	60.2	90.6	94.0	94.2	95.2
rougher spiral tailings	14.8	38.9	67.7	72.5	93.8
cleaner spiral tailings	45.0	66.8	83.6	89.3	88.5

* reported as weight % of mineral phase in sieve fraction

FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH
85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

SCULLY CONCENTRATOR

DISTRIBUTION OF FREE GRAINS* Mn MINERALS AND Mn GOETHITE

INDIVIDUAL SIEVE FRACTIONS

SAMPLE	+850 mic. +20 mesh	+212 mic. +65 mesh	+106 mic. +150 mesh	+53 mic. +270 mesh	-53 mic. -270 mesh
trommel screen undersize	47.9	38.3	47.0	36.8	48.2
sizing screen oversize	51.2	51.6	63.9	57.2	78.2
sizing screen undersize	45.0	47.3	40.3	54.8	57.3
rougher spiral middlings	44.5	43.1	31.3	45.1	42.1
rougher spiral concentrate	73.0	36.1	29.4	21.4	57.9
rougher spiral tailings	15.6	53.2	57.8	59.6	66.7
cleaner spiral tailings	46.5	46.9	46.2	24.7	44.9

* reported as weight % of mineral phase in sieve fraction

FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH 85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

SCULLY CONCENTRATOR

DISTRIBUTION OF FREE GRAINS*
GOETHITE FREE OF Mn

INDIVIDUAL SIEVE FRACTIONS

SAMPLE	+425 mic. +20 mesh	+212 mic. +65 mesh	+106 mic. +150 mesh	+53 mic. +270 mesh	-53 mic. -270 mesh
trommel screen undersize	48.2	55.0	65.4	59.9	78.3
sizing screen oversize	54.8	87.5	66.6	77.5	95.9
sizing screen undersize	59.7	51.1	69.0	72.6	84.4
rougher spiral middlings	41.6	38.9	51.8	75.4	86.8
rougher spiral concentrate	29.8	36.6	53.2	66.6	77.0
rougher spiral tailings	38.1	40.1	58.1	58.5	91.1
cleaner spiral tailings	42.6	56.2	67.9	50.5	87.9

* reported as weight % of mineral phase in sieve fraction

FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH
85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

SCULLY CONCENTRATOR

DISTRIBUTION OF FREE GRAINS*
SILICATES

INDIVIDUAL SIEVE FRACTIONS

SAMPLE	+850 mic. +20 mesh	+212 mic. +65 mesh	+106 mic. +150 mesh	+53 mic. +270 mesh	-53 mic. -270 mesh
trommel screen undersize	58.4	96.2	93.7	95.0	90.2
sizing screen oversize	81.6	97.6	93.1	89.8	97.1
sizing screen undersize	79.5	96.5	94.7	95.4	92.1
rougher spiral middlings	33.8	79.6	92.2	86.6	91.0
rougher spiral concentrate	27.1	91.4	85.9	86.8	96.3
rougher spiral tailings	65.2	94.3	97.3	95.3	91.6
cleaner spiral tailings	21.4	94.5	94.9	91.8	88.6

* reported as weight % of mineral phase in sieve fraction

FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH
85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

SCULLY CONCENTRATOR
CLEANER SPIRAL CONCENTRATE

DISTRIBUTION OF FREE GRAINS
ALL MINERAL PHASES

INDIVIDUAL SIEVE FRACTIONS

MINERAL PHASE	+850 mic. +20 mesh	+425 mic. +35 mesh	+212 mic. +65 mesh	+106 mic. +150 mesh	+53 mic. +270 mesh	+38 mic. +400 mesh	-38 mic. -400 mesh
A	92.4	94.5	94.1	93.2	94.8	94.2	93.2
B	78.5	67.8	62.3	62.2	44.6	42.3	80.2
C	54.3	23.2	53.0	53.3	47.6	44.0	85.7
D	13.8	42.0	76.2	78.5	73.7	96.7	93.6

* reported as weight % of mineral phase in sieve fraction

FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH 85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

LEGEND

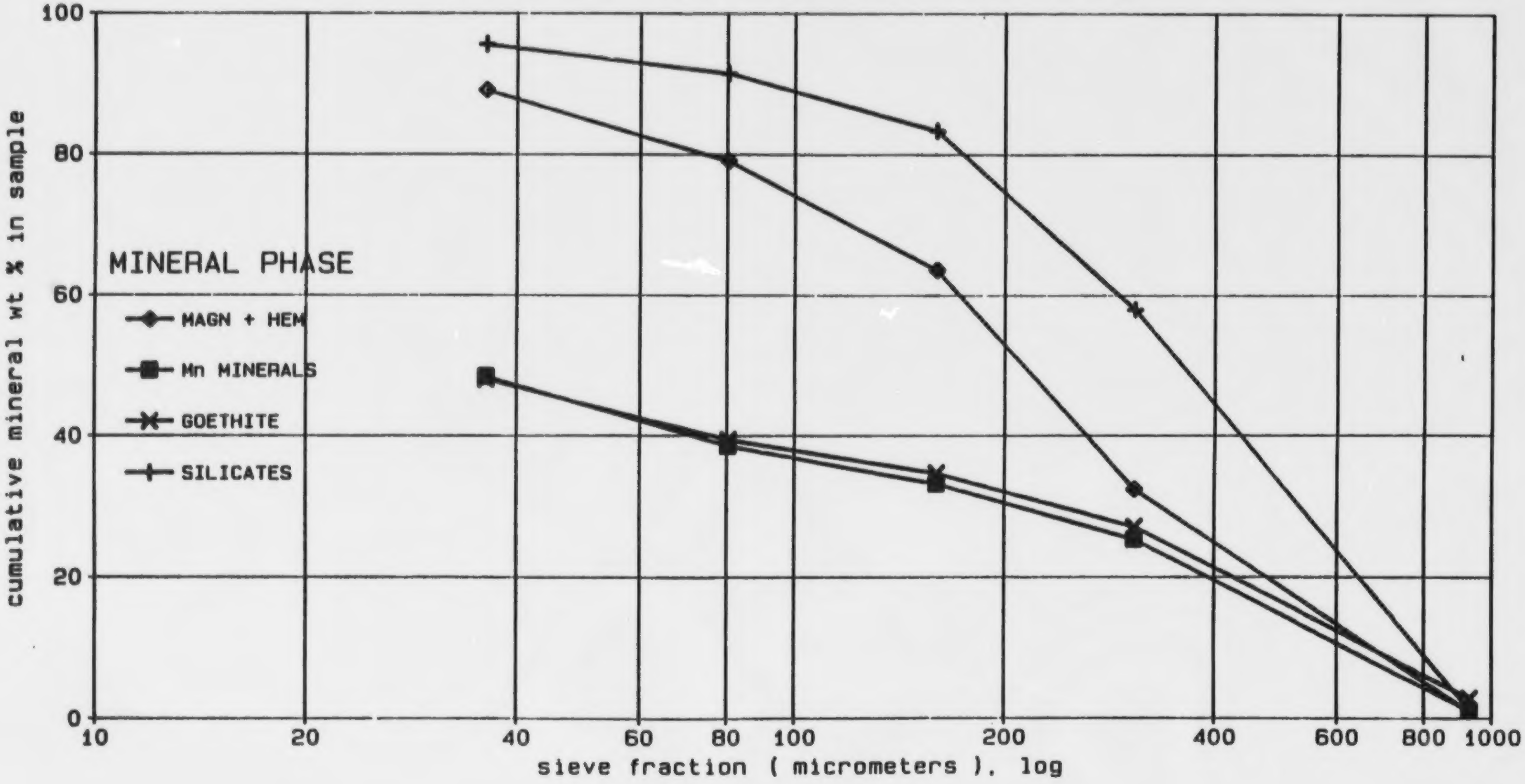
A : HEMATITE AND MAGNETITE
B : Mn MINERALS AND Mn GOETHITE
C : GOETHITE FREE OF Mn
D : SILICATES

APPENDIX G-2

Scully Concentrator,
All Mineral Phases
Cumulative Distribution of Free Grains

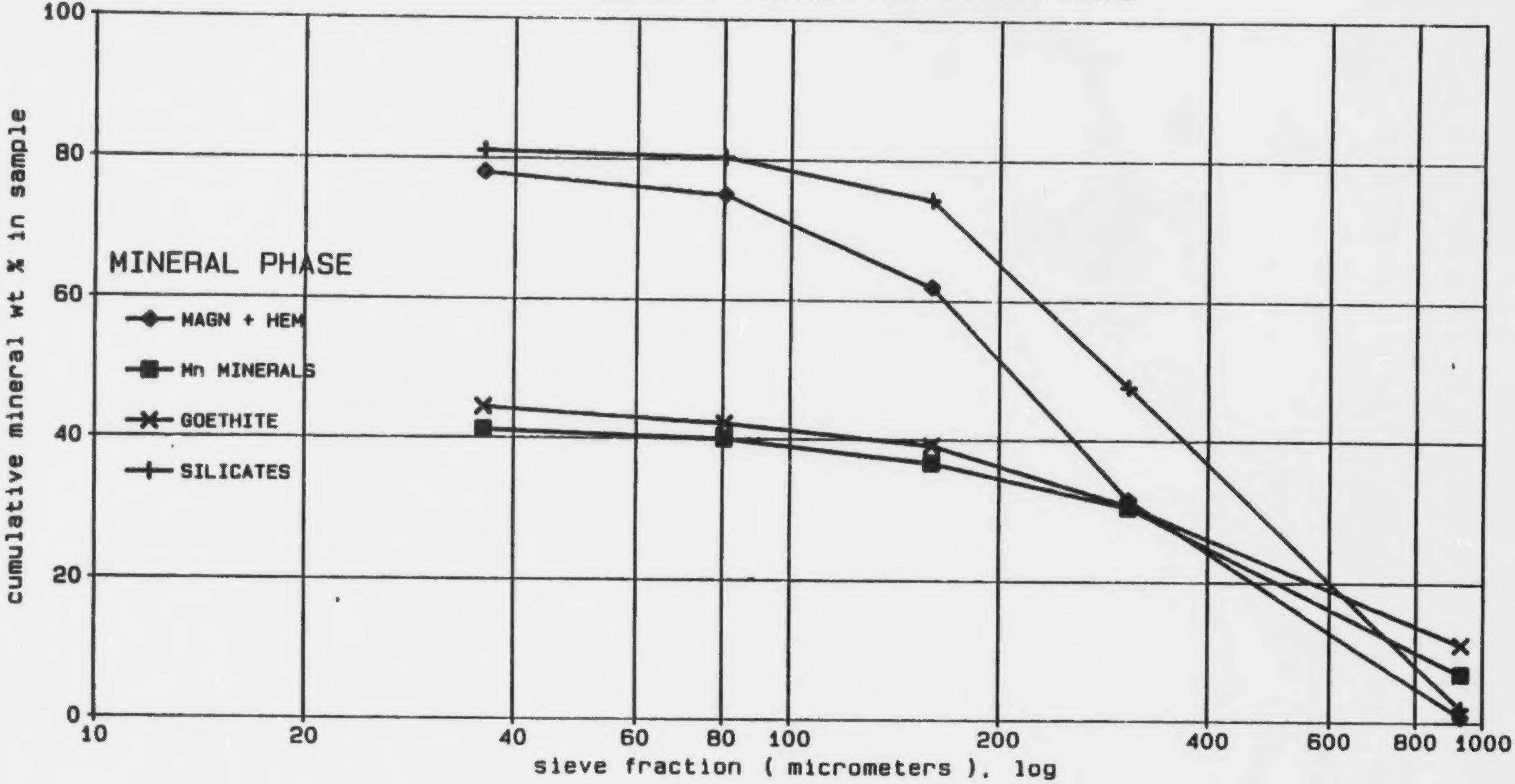
SSU
RSM
RSC
RST
CSC
CST

SCULLY CONCENTRATOR, SSU
CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS

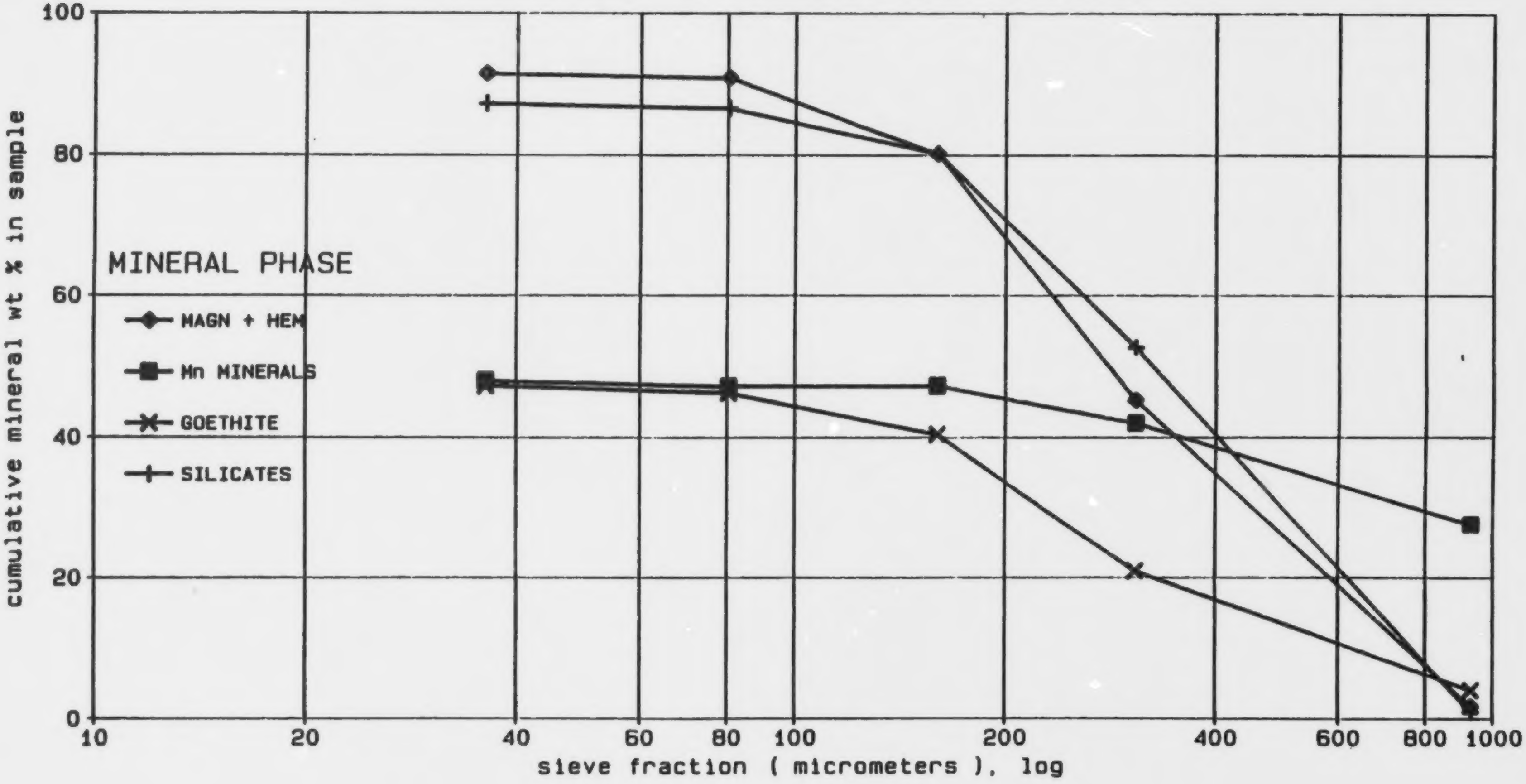


SCULLY CONCENTRATOR, RSM

CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS

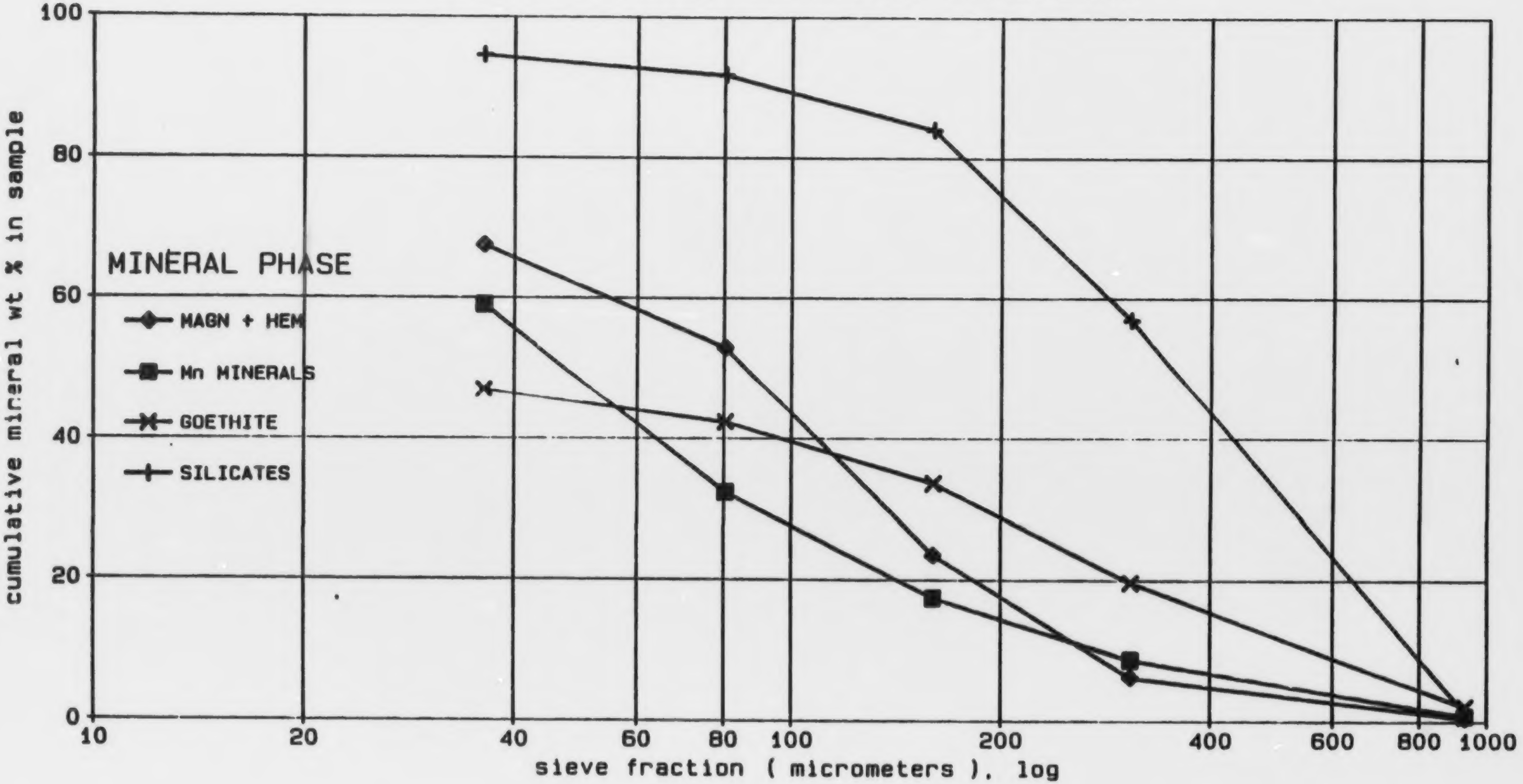


SCULLY CONCENTRATOR, RSC
CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS



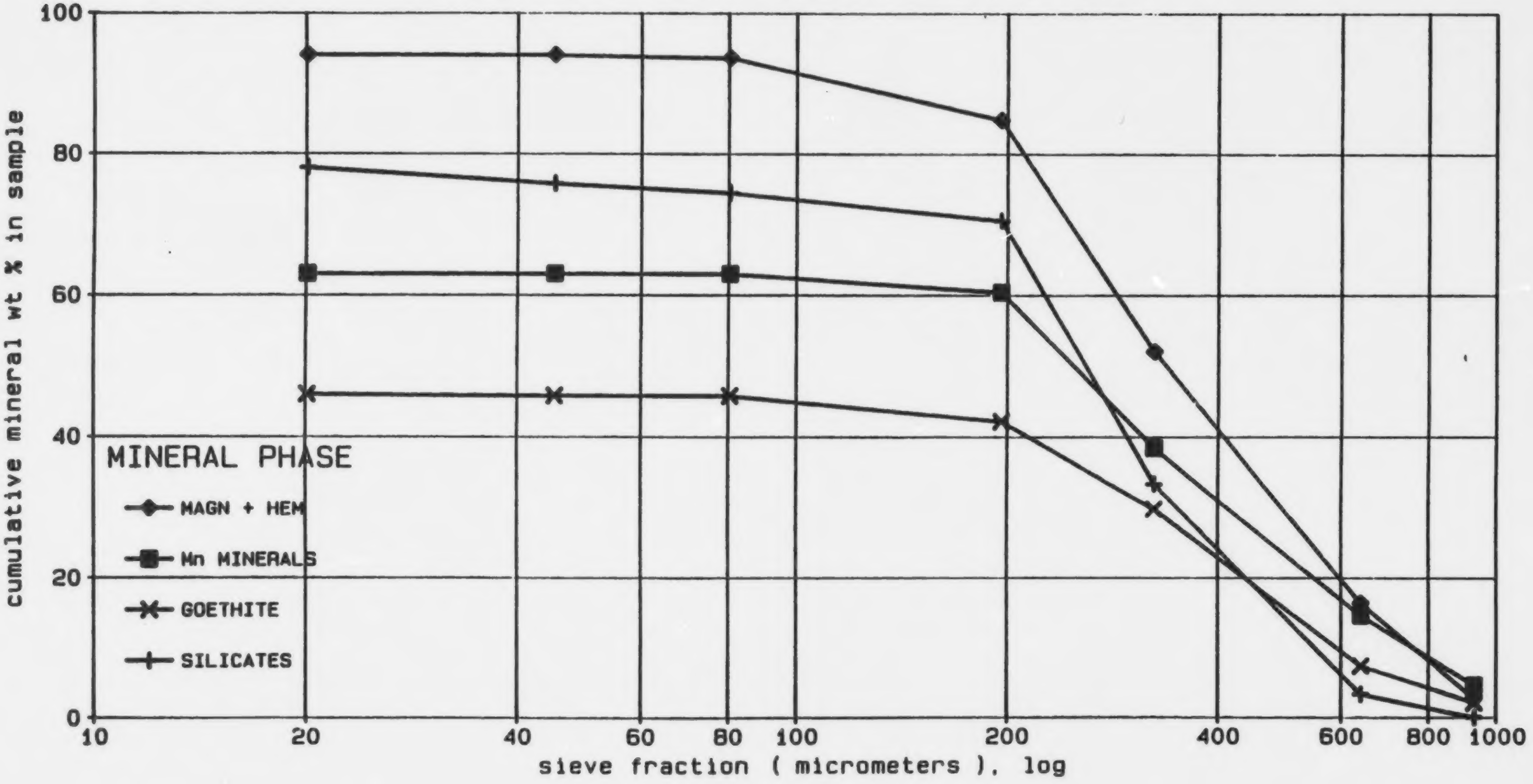
SCULLY CONCENTRATOR, RST

CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS



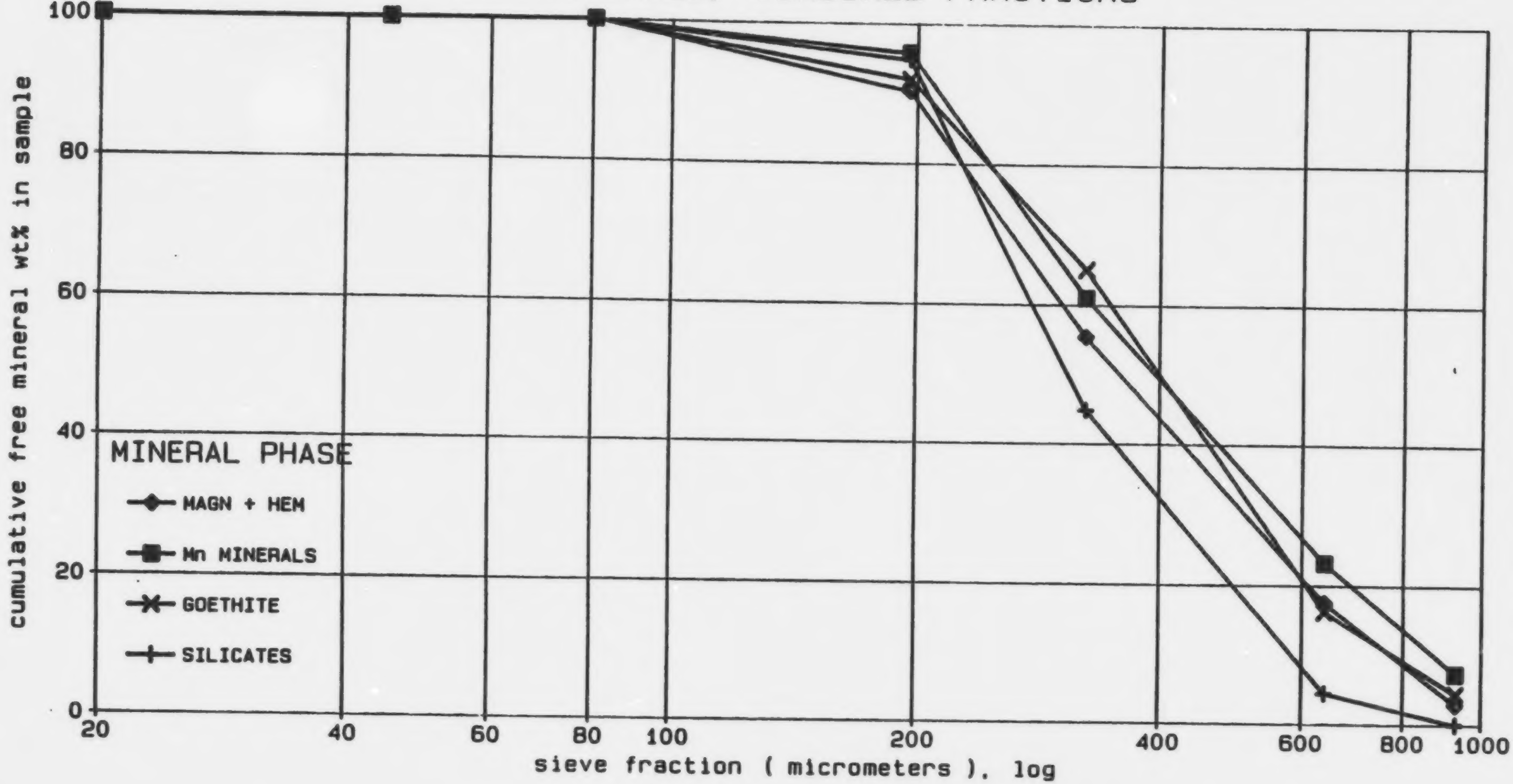
SCULLY CONCENTRATOR, CSC

CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS



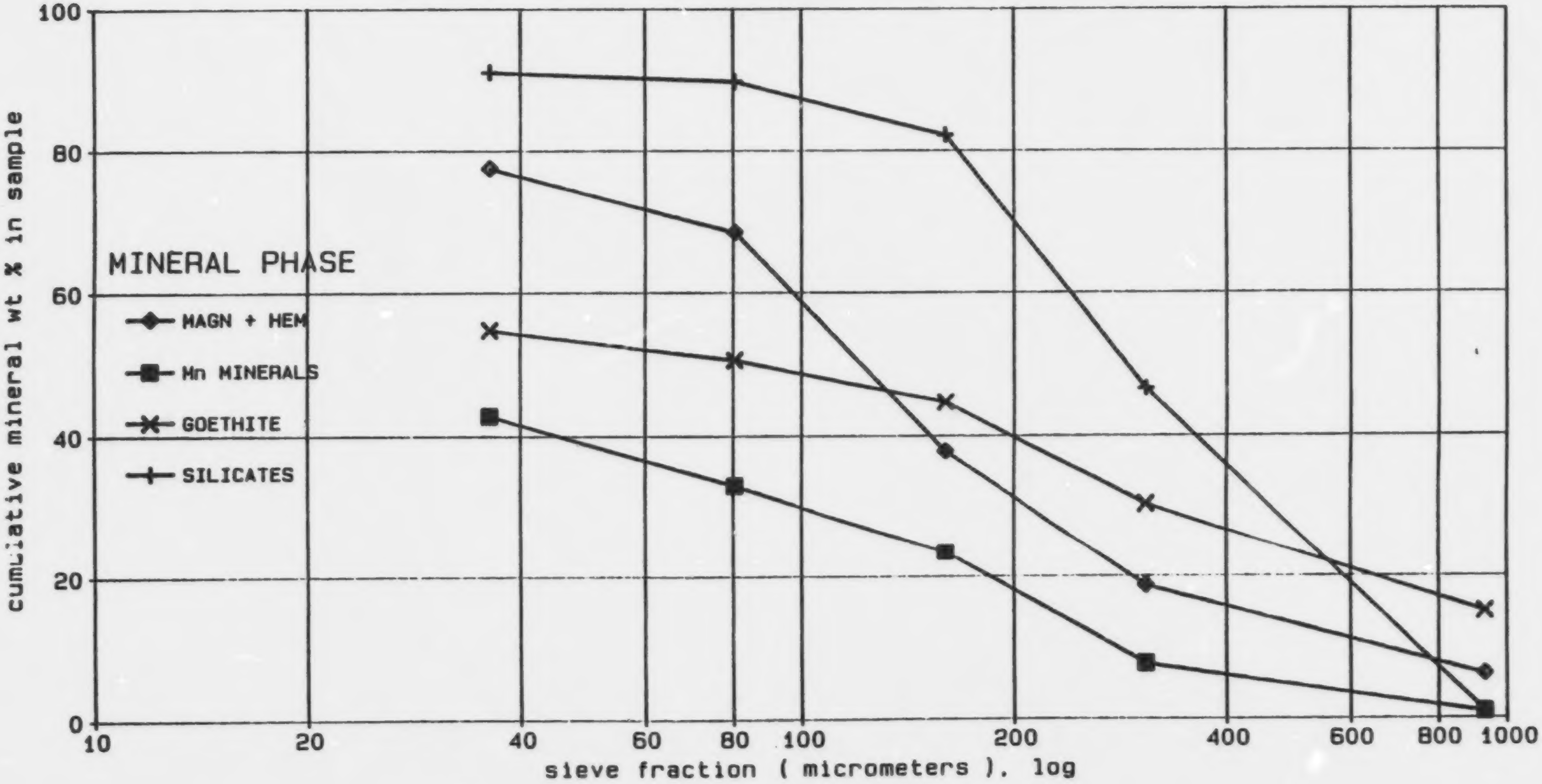
SCULLY CONCENTRATOR, CSC

CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS



SCULLY CONCENTRATOR, CST

CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS



APPENDIX G-3

Scully Concentrator,
All Mineral Phases
Distribution of Free Grains
Combined Fractions

SCULLY CONCENTRATOR

DISTRIBUTION OF FREE GRAINS*
ALL MINERAL PHASES

COMBINED FRACTIONS

SAMPLE	MINERAL PHASE			
	A	B	C	D
trommel screen undersize	88.6	42.6	54.1	89.4
sizing screen oversize	85.7	54.7	62.1	90.6
sizing screen undersize	91.2	46.2	62.8	94.5
rougher spiral middlings	74.4	39.9	42.4	79.3
rougher spiral concentrate	91.1	45.0	40.7	87.3
rougher spiral tailings	73.2	56.6	45.3	93.1
cleaner spiral concentrate	91.1	71.8	29.5	85.1
cleaner spiral tailings	74.6	41.8	51.0	91.4

* reported as weight % of mineral phase in sample

FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH
85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

LEGEND

A: HEMATITE AND MAGNETITE
B: Mn MINERALS AND Mn GOETHITE
C: GOETHITE FREE OF Mn
D: SILICATES

APPENDIX H-1

ORF Test,
All Mineral Phases
Distribution of Free Grains
Individual Sieve Fractions

DISTRIBUTION OF FREE GRAINS*
HEMATITE AND MAGNETITE

INDIVIDUAL SIEVE FRACTIONS

SAMPLE	+212 mic. +65 mesh	+106 mic. +150 mesh	+53 mic. +270 mesh	-53 mic. -270 mesh
mill product -20 Mesh	90.8	87.6	92.6	91.6
mill product -28 Mesh	91.3	92.8	90.9	83.4
middlings	25.0	40.0	69.1	92.6
concentrate	93.7	89.9	96.2	97.2
tailings	9.2	42.2	86.0	94.6

* reported as weight % of mineral phase in sieve fract

ORF TEST

DISTRIBUTION OF FREE GRAINS*
Mn MINERALS AND Mn GOETHITE

INDIVIDUAL SIEVE FRACTIONS

SAMPLE	+212 mic. +65 mesh	+106 mic. +150 mesh	+53 mic. +270 mesh	-53 mic. -270 mesh
mill product -20 Mesh	58.0	63.6	65.7	63.9
mill product -28 Mesh	57.0	58.9	65.8	67.4
middlings	32.5	43.9	48.7	67.4
concentrate	50.2	33.4	66.1	41.0
tailings	4.9	78.5	84.7	77.7

* reported as weight % of mineral phase in sieve fraction

FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH
85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

ORF TEST

DISTRIBUTION OF FREE GRAINS*
GOETHITE FREE OF Mn

INDIVIDUAL SIEVE FRACTIONS

SAMPLE	+212 mic. +65 mesh	+106 mic. +150 mesh	+53 mic. +270 mesh	-53 mic. -270 mesh
mill product -20 Mesh	46.5	39.6	42.1	55.2
mill product -28 Mesh	34.9	33.0	53.5	49.6
middlings	30.1	46.9	58.2	88.3
concentrate	37.0	34.4	55.4	44.0
tailings	32.4	40.1	85.6	84.9

* reported as weight % of mineral phase in sieve fraction

FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH 85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

ORF TEST

DISTRIBUTION OF FREE GRAINS*
SILICATES

INDIVIDUAL SIEVE FRACTIONS

SAMPLE	+212 mic. +65 mesh	+106 mic. +150 mesh	-53 mic. +270 mesh	-53 mic. -270 mesh
mill product -20 Mesh	93.8	95.1	89.9	89.2
mill product -28 Mesh	92.9	92.7	91.6	88.2
middlings	85.0	97.6	93.3	86.7
concentrate	73.1	74.0	91.1	96.7
tailings	95.2	97.8	97.9	96.4

* reported as weight % of mineral phase in sieve fraction

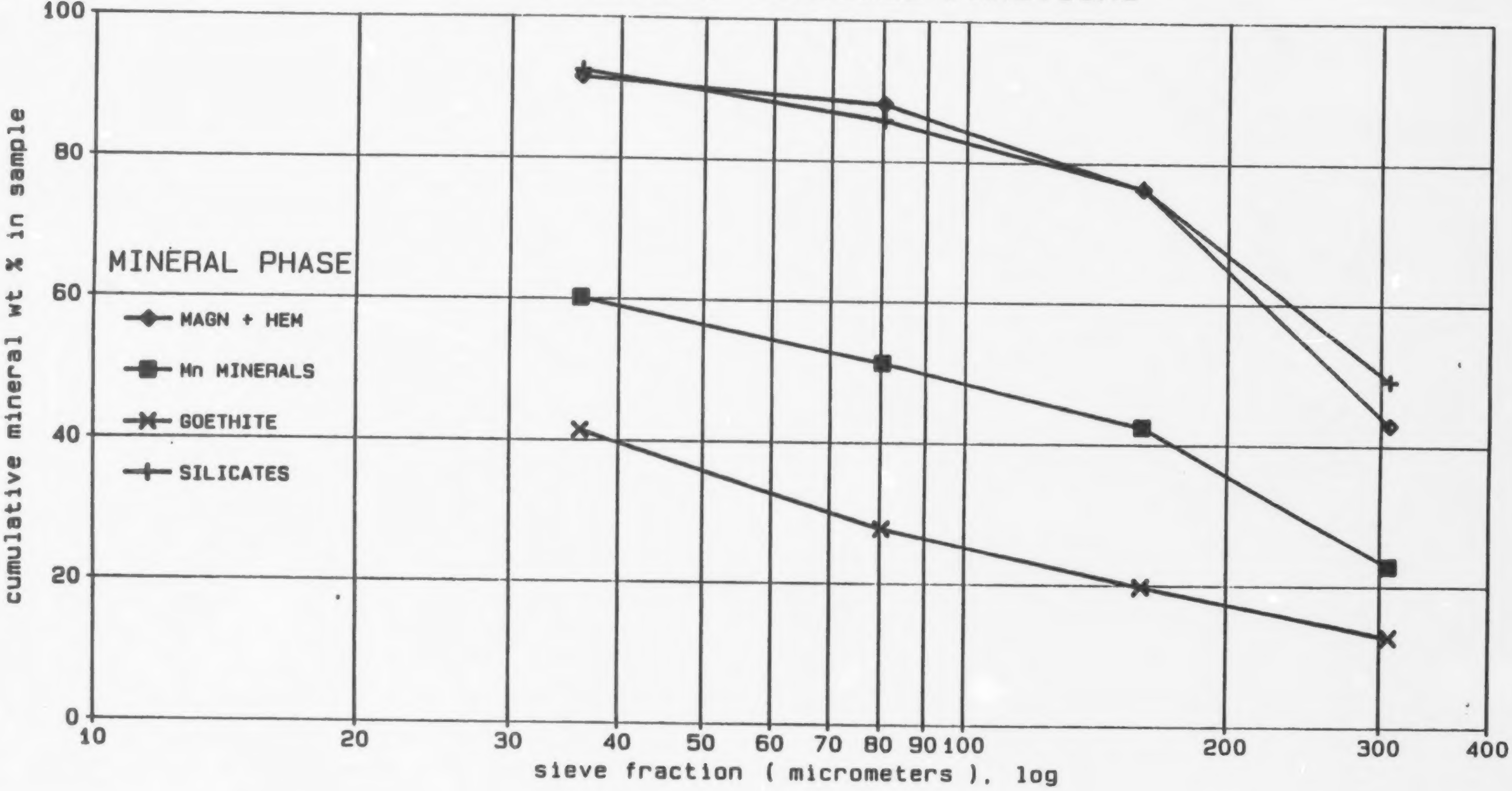
FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH
85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

APPENDIX H-2

ORF Test,
All Mineral Phases
Cumulative Distribution of Free Grains
Mill Product -28 Mesh
Concentrate
Tailings

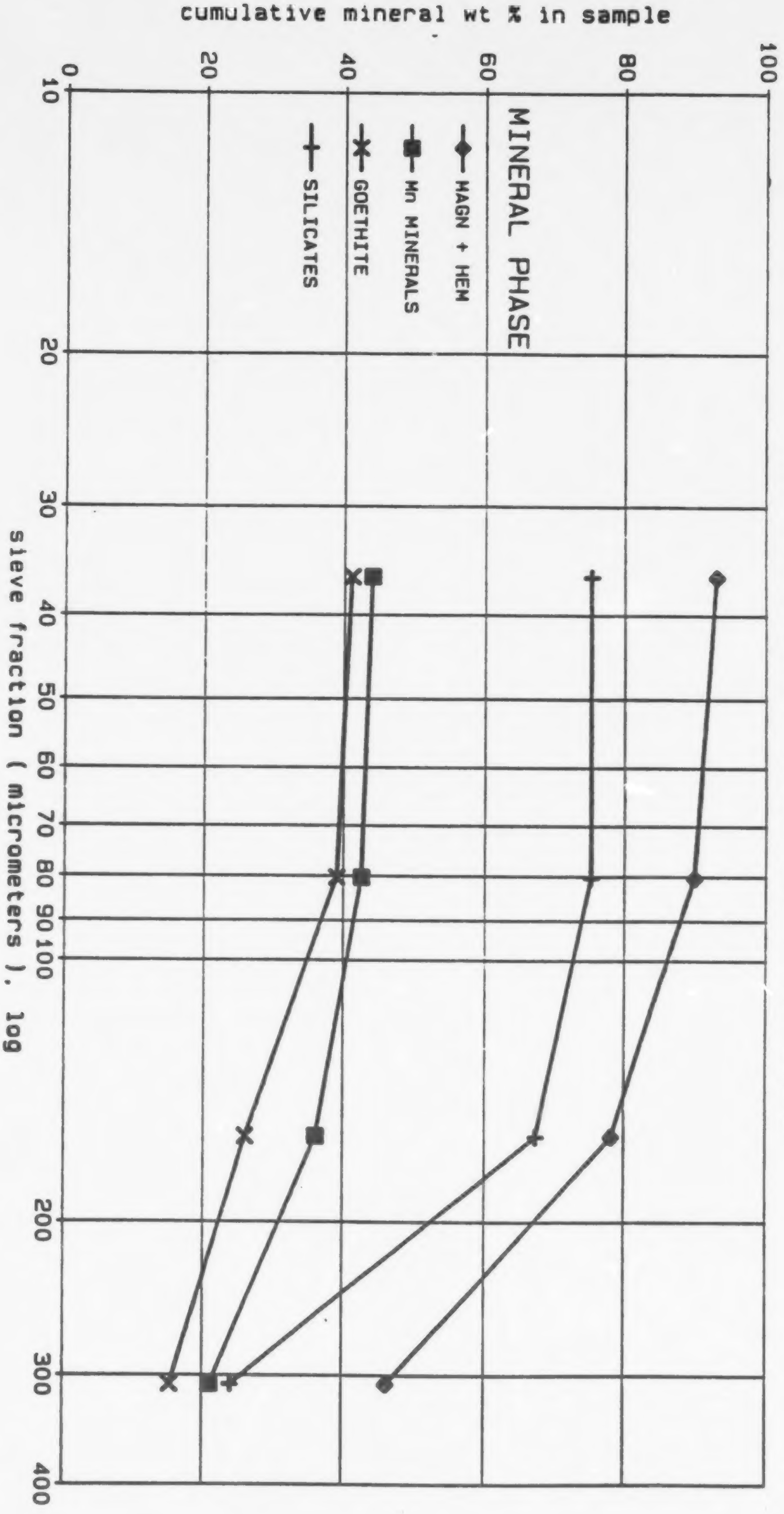
ORF TEST, MILL PRODUCT -28 MESH

CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS



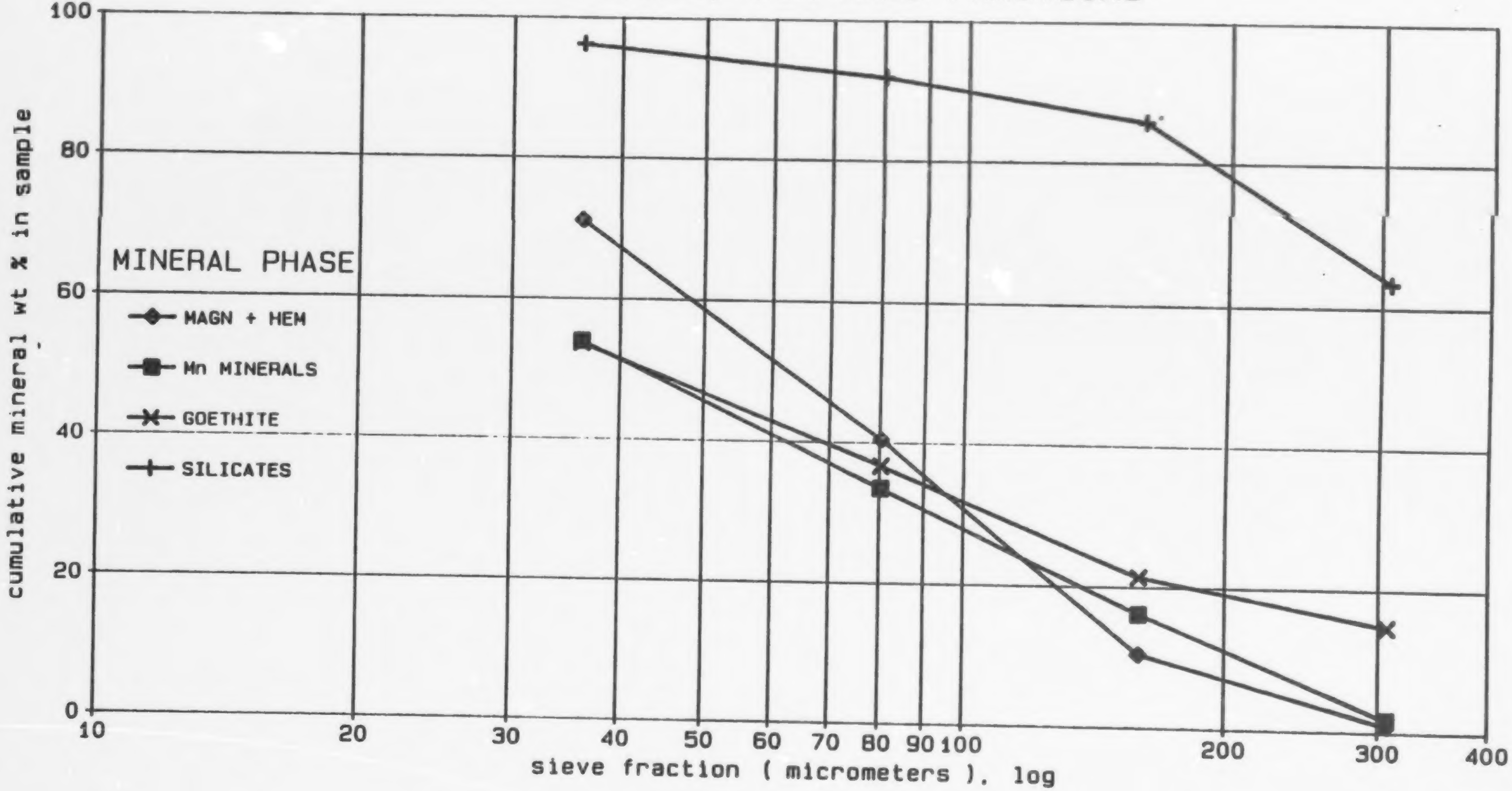
ORF TEST, CONCENTRATE

CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS



ORF TEST, TAILINGS

CUMULATIVE DISTRIBUTION OF FREE GRAINS
ALL MINERALS, COMBINED FRACTIONS



APPENDIX H-3

ORF Test,
All Mineral Phases
Distribution of Free Grains
Combined Fractions

ORF TEST

DISTRIBUTION OF FREE GRAINS*
ALL MINERAL PHASES

COMBINED FRACTIONS

SAMPLE	MINERAL PHASE			
	A	B	C	E
mill product -20 Mesh	89.5	59.8	42.1	91.6
mill product -28 Mesh	90.4	60.1	45.2	93.5
middlings	50.7	40.5	37.7	89.4
concentrate	92.3	44.5	39.2	74.6
tailings	72.1	56.3	53.9	95.6

* reported as weight % of mineral phase in sample

FREE GRAIN OF MINERAL PHASE = ORE PARTICLE IN WHICH
85 OR MORE PERCENT OF VOLUME IS OCCUPIED BY THIS PHASE

LEGEND

A : HEMATITE AND MAGNETITE
B : Mn MINERALS AND Mn GOETHITE
C : GOETHITE FREE OF Mn
D : SILICATES

APPENDIX I-1

Scully Concentrator,
All Mineral Phases
Distribution of Mineral Phases
Combined Fractions
All Samples

SCULLY CONCENTRATOR

DISTRIBUTION OF MINERAL PHASES*

COMBINED FRACTIONS

SAMPLE	MINERAL PHASE			
	A	B	C	D
trommel screen undersize	47.0	4.4	4.9	43.7
sizing screen oversize	44.5	5.0	8.1	42.4
sizing screen undersize	47.9	3.8	4.7	43.6
rougher spiral middlings	45.8	7.0	11.8	35.4
rougher spiral concentrate	77.6	4.5	2.9	15.0
rougher spiral tailings	19.4	4.0	12.0	64.6
cleaner spiral concentrate	86.4	3.4	2.6	7.6
cleaner spiral tailings	36.2	5.4	8.5	49.9

* reported as sample wt %

LEGEND

A : HEMATITE AND MAGNETITE
B : Mn MINERALS AND Mn GOETHITE
C : GOETHITE FREE OF Mn
D : SILICATES

APPENDIX I-2

Scully Concentrator, Contribution of Mineral Phases from Individual Sieve Fractions of Products to Total Weight Phases in Products

SCULLY CONCENTRATOR

CONTRIBUTION OF HEMATITE AND MAGNETITE
FROM INDIVIDUAL SIEVE FRACTIONS OF PRODUCT
TO TOTAL WEIGHT OF HEMATITE AND MAGNETITE
IN PRODUCT*

FRACTION				S-[illegible]			
	TSU	SSD	SSU	RSM	RSU	RST	CST
+20 mesh	7.9	37.3	1.5	3.3	2.8	3.6	14.1
+65 mesh	39.8	44.3	42.8	45.0	48.1	14.9	18.5
+150 mesh	34.9	9.9	33.6	34.5	37.1	25.3	22.9
+270 mesh	12.6	6.1	16.5	14.2	11.3	40.7	34.3
-270 mesh	4.9	2.5	5.6	3.1	.6	15.5	10.2
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* reported as wt% of mineral phase in product

SCULLY CONCENTRATOR

CONTRIBUTION OF Mn MINERALS AND Mn GOETHITE FROM INDIVIDUAL SIEVE FRACTIONS OF PRODUCT TO TOTAL WEIGHT OF Mn MINERALS AND Mn GOETHITE IN PRODUCT*

FRACTION	PRODUCT						
	TSU	SSO	SSU	RSM	RSC	RST	CST
+20 mesh	20.5	60.0	2.4	15.7	37.8	5.0	1.9
+65 mesh	29.5	24.0	51.2	54.3	40.0	15.0	14.8
+150 mesh	18.2	6.0	19.5	20.0	17.8	15.0	33.3
+270 mesh	13.6	4.0	9.8	7.1	4.4	25.0	27.8
-270 mesh	18.2	6.0	17.1	2.9	.0	40.0	22.2
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* reported as wt% of mineral phase in product

SCULLY CONCENTRATOR

CONTRIBUTION OF GOETHITE FREE OF Mn
FROM INDIVIDUAL SIEVE FRACTIONS OF PRODUCT
TO TOTAL WEIGHT OF GOETHITE FREE OF Mn
IN PRODUCT*

FRACTION	PRODUCT						
	TSU	SSO	SSU	RSM	RSC	RST	CST
+20 mesh	44.9	67.9	6.4	27.1	13.8	5.8	35.3
+65 mesh	32.7	23.5	51.1	50.0	24.1	43.3	27.1
+150 mesh	8.2	3.7	19.1	16.1	51.7	24.2	21.2
+270 mesh	10.2	2.5	8.5	4.2	10.3	18.3	11.8
-270 mesh	4.1	2.5	14.9	2.5	.0	8.3	4.7
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* reported as wt% of mineral phase in product

SCULLY CONCENTRATOR

CONTRIBUTION OF SILICATES
FROM INDIVIDUAL SIEVE FRACTIONS OF PRODUCT
TO TOTAL WEIGHT OF SILICATES
IN PRODUCT*

FRACTION	PRODUCT						
	TSU	SSO	SSU	RSM	RSC	RST	CST
+20 mesh	11.7	34.4	1.6	5.9	3.3	2.2	4.6
+65 mesh	59.5	44.1	58.7	57.3	56.7	58.8	48.3
+150 mesh	17.8	12.3	26.8	29.1	32.0	27.9	37.5
+270 mesh	7.1	7.5	8.5	6.8	7.3	8.2	8.2
-270 mesh	3.9	1.7	4.4	.8	.7	2.9	1.4
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* reported as wt% of mineral phase in product

SCULLY CONCENTRATOR, CLEANER SPIRAL CONCENTRATE

CONTRIBUTION OF MINERAL PHASES
FROM INDIVIDUAL SIEVE FRACTIONS OF PRODUCT
TO TOTAL WEIGHT OF MINERAL PHASES
IN PRODUCT*

FRACTION	MINERAL PHASE			
	A	B	C	D
+20 mesh	2.9	5.9	3.8	.0
+35 mesh	14.5	14.7	23.1	7.9
+65 mesh	37.8	38.2	42.3	39.5
+150 mesh	35.2	35.3	23.1	47.4
+270 mesh	9.6	5.9	7.7	5.3
+400 mesh	.2	.0	.0	1.3
-400 mesh	.0	.0	.0	.0
TOTAL	100.0	100.0	100.0	100.0

LEGEND:

A: HEMATITE AND MAGNETITE
B: Mn MINERALS AND Mn GOETHITE
C: GOETHITE FREE OF Mn
D: SILICATES

* reported as wt% of mineral phase in product

APPENDIX J-1

ORF Test,
All Mineral Phases
Distribution of Mineral Phases
Combined Fractions
All Samples

ORF TEST

DISTRIBUTION OF MINERAL PHASES*

COMBINED FRACTIONS

SAMPLE	MINERAL PHASE			
	A	B	C	D
mill product -20 M	52.0	2.9	4.0	41.1
mill product -28 M	50.5	3.0	3.3	43.2
middlings	47.5	4.0	16.1	32.4
concentrate	88.2	3.1	2.9	5.8
tailings	27.1	3.8	9.0	60.1

* reported as sample wt %

LEGEND

A : HEMATITE AND MAGNETITE
B : Mn MINERALS AND Mn GOETHITE
C : GOETHITE FREE OF Mn
D : SILICATES

APPENDIX J-2

ORF Test,
Contribution of Mineral Phases from Individual Sieve Fractions of Products to Total Weight of Phases in Products

ORF TEST

CONTRIBUTION OF HEMATITE AND MAGNETITE FROM INDIVIDUAL SIEVE FRACTIONS OF PRODUCT TO TOTAL WEIGHT OF HEMATITE AND MAGNETITE IN PRODUCT*

FRACTION	PRODUCT				
	M.P. -20 M	M.P. -28 M	MID.	CONC.	TAIL
+65 mesh	68.3	46.9	42.5	49.2	40.2
+150 mesh	18.1	36.0	34.9	35.6	22.5
+270 mesh	8.3	13.1	13.5	12.1	14.8
-270 mesh	5.4	4.0	9.1	3.1	22.5
TOTAL	100.0	100.0	100.0	100.0	100.0

* reported as mineral wt% in product

ORF TEST

CONTRIBUTION OF Mn MINERALS AND Mn GOETHITE
FROM INDIVIDUAL SIEVE FRACTIONS OF PRODUCT
TO TOTAL WEIGHT OF Mn MINERALS AND Mn GOETHITE
IN PRODUCT*

FRACTION	PRODUCT				
	M.P. -20 M	M.P. -28 M	MID.	CONC.	TAIL
+65 mesh	44.8	40.0	52.5	41.9	44.7
+150 mesh	34.5	33.3	22.5	45.2	18.4
+270 mesh	10.3	13.3	17.5	9.7	10.5
-270 mesh	10.3	13.3	7.5	3.2	26.3
TOTAL	100.0	100.0	100.0	100.0	100.0

* reported as mineral wt% in product

ORF TEST

CONTRIBUTION OF GOETHITE FREE OF Mn
FROM INDIVIDUAL SIEVE FRACTIONS OF PRODUCT
TO TOTAL WEIGHT OF GOETHITE FREE OF Mn
IN PRODUCT*

FRACTION	PRODUCT				
	M.P. -20 M	M.P. -28 M	MID.	CONC.	TAIL
+65 mesh	60.0	36.4	58.4	41.4	55.6
+150 mesh	22.5	21.3	24.2	31.0	16.7
+270 mesh	7.5	15.2	13.0	24.1	7.8
-270 mesh	10.0	27.3	4.3	3.4	20.0
TOTAL	100.0	100.0	100.0	100.0	100.0

* reported as mineral wt% in product

ORF TEST

CONTRIBUTION OF SILICATES
FROM INDIVIDUAL SIEVE FRACTIONS OF PRODUCT
TO TOTAL WEIGHT OF SILICATES
IN PRODUCT*

FRACTION	PRODUCT				
	M.P. -20 M	M.P. -28 M	MID.	CONC.	TAIL
+65 mesh	63.3	52.8	22.8	32.8	66.6
+150 mesh	26.8	29.4	66.4	58.6	22.8
+270 mesh	6.8	10.4	7.7	8.6	6.2
-270 mesh	3.2	7.4	3.1	.0	4.5
TOTAL	100.0	100.0	100.0	100.0	100.0

* reported as mineral wt% in product

APPENDIX K-1

Scully Concentrator
Mineral Balance

SCULLY CONCENTRATOR

MINERAL BALANCE*

STREAM	stream flow wt%	MINERAL PHASE			
		A	B	C	D
sizin screen undersize	100.0	100.0	100.0	100.0	100.0
rougher spiral middlings	3.6	3.2	6.4	7.4	3.3
rougher spiral tailings	46.0	17.2	46.9	72.4	83.3
rougher spiral concentrate	57.5	85.1	58.0	31.9	21.5
cleaner spiral tailings	8.7	6.1	12.2	12.5	11.6
cleaner spiral concentrate	48.8	79.0	45.9	19.4	9.9
middlings cyclone underflow	7.1	5.5	11.3	11.8	8.1
middlings cyclone overflow	5.3	3.9	7.3	8.2	6.8

* reported as percentage of mineral phase in spiral circuit feed

LEGEND

A: HEMATITE AND MAGNETITE
B: Mn MINERALS AND Mn GOETHITE
C: GOETHITE FREE OF Mn
D: SILICATES

APPENDIX K-2

Scully Concentrator
Free Grains Balance

SCULLY CONCENTRATOR

FREE GRAINS BALANCE*

STREAM	stream flow wt%	MINERAL PHASE A	B	C	D
sizin screen undersize	100.0	100.0	100.0	100.0	100.0
rougher spiral middlings	3.6	2.7	4.9	6.4	2.9
rougher spiral tailings	46.0	13.8	45.0	75.7	84.7
rougher spiral concentrate	57.5	88.1	59.0	28.6	20.3
cleaner spiral tailings	8.7	5.1	9.5	11.8	11.7
cleaner spiral concentrate	48.8	83.0	49.4	16.8	8.6
middlings cyclone underflow	7.1	4.6	8.9	10.6	7.9
middlings cyclone overflow	5.3	3.2	5.6	7.5	6.7

* reported as percentage of free grains of mineral phase in spiral circuit feed

LEGEND

A: HEMATITE AND MAGNETITE
B: Mn MINERALS AND Mn GOETHITE
C: GOETHITE FREE OF Mn
D: SILICATES

APPENDIX L

Scully Concentrator
Free Grains Balance
Individual Sieve Fractions

SCULLY CONCENTRATOR

FREE GRAINS BALANCE, INDIVIDUAL SIEVE FRACTIONS*

HEMATITE AND MAGNETITE

PRODUCT	wt % of product	total sample	sieve fraction (mesh)				
			+20	+65	+150	+270	-270
sizing screen undersize	100.0	100.0	1.2	37.3	36.9	18.5	6.1
rougher spiral middlings	3.6	2.7	.0	1.1	1.1	.5	.1
rougher spiral tailings	46.0	13.8	.1	1.3	3.5	6.0	2.9
rougher spiral concentrate	57.5	88.1	1.6	42.0	33.6	10.3	.6
cleaner spiral tailings	8.7	5.1	.4	.8	1.3	2.0	.6

	wt % of product	total sample	sieve fraction (mesh)						
			+20	+35	+65	+150	+270	+400	-400
cleaner spiral concentrate	48.8	83.0	2.4	12.1	31.4	28.9	8.1	.2	.0

* reported as wt% of free grains entering spirals

SCULLY CONCENTRATOR

FREE GRAINS BALANCE, INDIVIDUAL SIEVE FRACTIONS*

Mn MINERALS AND Mn GOETHITE

PRODUCT	wt % of product	total sample	sieve fraction (mesh) +20	+65	+150	+270	-270
sizing screen undersize	100.0	100.0	2.3	50.1	16.3	11.1	20.2
rougher spiral middlings	3.6	4.9	.8	2.8	.7	.4	.1
rougher spiral tailings	46.0	45.0	.5	3.6	6.3	11.3	23.3
rougher spiral concentrate	57.5	59.0	16.8	26.8	12.3	3.1	.0
cleaner spiral tailings	8.7	9.5	.2	2.1	2.6	1.8	2.8

	wt % of product	total sample	sieve fraction (mesh) +20	+35	+65	+150	+270	+400	-400
cleaner spiral concentrate	48.8	49.4	3.6	7.8	18.7	17.2	2.1	.0	.0

* reported as wt% of free grains entering spirals

SCULLY CONCENTRATOR

FREE GRAINS BALANCE, INDIVIDUAL SIEVE FRACTIONS*

GOETHITE FREE OF Mn

PRODUCT	wt % of product	total sample	sieve fraction (mesh) +20	+65	+150	+270	-270
sizing screen undersize	100.0	100.0	6.2	42.2	21.4	10.0	20.3
rougher spiral middlings	3.6	6.4	1.7	2.8	1.2	.5	.2
rougher spiral tailings	46.0	75.7	3.2	25.3	20.5	15.6	11.1
rougher spiral concentrate	57.5	28.6	2.5	5.3	16.6	4.2	.0
cleaner spiral tailings	8.7	11.8	3.2	3.3	3.1	1.3	.9

	wt % of product	total sample	+20	+35	+65	sieve fraction (mesh) +150	+270	+400	-400
cleaner spiral concentrate	48.0	16.8	.7	1.9	7.9	5.0	1.3	.0	.0

* reported as wt% of free grains entering spirals

SCULLY CONCENTRATOR

FREE GRAINS BALANCE, INDIVIDUAL SIEVE FRACTIONS*

SILICATES

PRODUCT	wt % of product	total sample	sieve fraction (mesh) +20	+65	+150	+270	-270
sizing screen undersize	100.0	100.0	1.3	59.4	26.6	8.5	4.2
rougher spiral middlings	3.6	2.9	.1	1.6	1.0	.2	.0
rougher spiral tailings	46.0	84.7	.5	48.6	25.0	7.6	3.0
rougher spiral concentrate	57.5	20.3	.1	7.2	3.8	9.0	.1
cleaner spiral tailings	8.7	11.7	.1	5.9	4.6	1.0	.2

	wt % of product	total sample	sieve fraction (mesh) +20	+35	+65	+150	+270	+400	-400
cleaner spiral concentrate	48.8	8.6	.0	.4	3.5	4.3	.3	.1	.0

* reported as wt% of free grains entering spirals

APPENDIX M

Scully Concentrator
Locked Grains Balance
Individual Sieve Fractions

SCULLY CONCENTRATOR

LOCKED GRAINS BALANCE, INDIVIDUAL SIEVE FRACTIONS*

HEMATITE AND MAGNETITE

PRODUCT	wt % of product	total sample	sieve fraction (mesh) +20	+65	+150	+270	-270
sizing screen undersize	100.0	100.0	3.0	71.9	16.1	6.0	3.0
rougher spiral middlings	3.6	7.4	.8	4.7	1.4	.3	.1
rougher spiral tailings	46.0	49.4	4.7	13.9	12.4	17.0	1.5
rougher spiral concentrate	57.5	54.9	7.2	29.0	14.3	4.2	.2
cleaner spiral tailings	8.7	12.3	4.2	3.4	2.1	2.0	.6

	wt % of product	total sample	+20	+35	+65	sieve fraction (mesh) +150	+270	+400	-400
cleaner spiral concentrate	48.8	42.5	5.5	15.4	16.5	3.5	.1	.0	.0

* reported as wt% of free grains entering spirals

SCULLY CONCENTRATOR

LOCKED GRAINS BALANCE, INDIVIDUAL SIEVE FRACTIONS*

Mn MINERALS AND Mn GOETHITE

PRODUCT	wt % of product	total sample	sieve fraction (mesh) +20	+65	+150	+270	-270
sizing screen undersize	100.0	100.0	2.6	52.2	22.5	8.5	14.1
rougher spiral middlings	3.6	6.4	.9	3.4	1.5	.4	.2
rougher spiral tailings	46.0	53.9	5.5	9.2	8.3	13.3	17.5
rougher spiral concentrate	57.5	45.9	9.0	22.6	11.1	3.1	.0
cleaner spiral tailings	8.7	3.9	.1	1.0	1.0	.9	1.0

	wt % of product	total sample	sieve fraction (mesh) +20	+35	+65	+150	+270	+400	-400
cleaner spiral concentrate	48.8	42.0	6.7	11.3	12.0	10.0	2.0	.0	.0

* reported as wt% of free grains entering spirals

SCULLY CONCENTRATOR

LOCKED GRAINS BALANCE, INDIVIDUAL SIEVE FRACTIONS*

GOETHITE FREE OF Mn

PRODUCT	wt % of product	total sample	sieve fraction (mesh) +20	+65	+150	+270	-270
sizing screen undersize	100.0	100.0	6.7	65.5	15.6	6.1	6.1
rougher spiral middlings	3.6	4.6	1.3	2.5	.6	.1	.0
rougher spiral tailings	46.0	29.2	2.2	15.8	6.2	4.6	.5
rougher spiral concentrate	57.5	71.0	13.1	20.6	32.6	4.7	.0
cleaner spiral tailings	8.7	6.8	3.0	1.8	1.0	.9	.1

	wt % of product	total sample	+20	+35	+65	sieve fraction (mesh) +150	+270	+400	-400
cleaner spiral concentrate	48.8	64.2	2.0	20.3	22.8	14.4	4.6	.0	.0

* reported as wt% of free grains entering spirals

SCULLY CONCENTRATOR

LOCKED GRAINS BALANCE, INDIVIDUAL SIEVE FRACTIONS*

GOETHITE FREE OF Mn

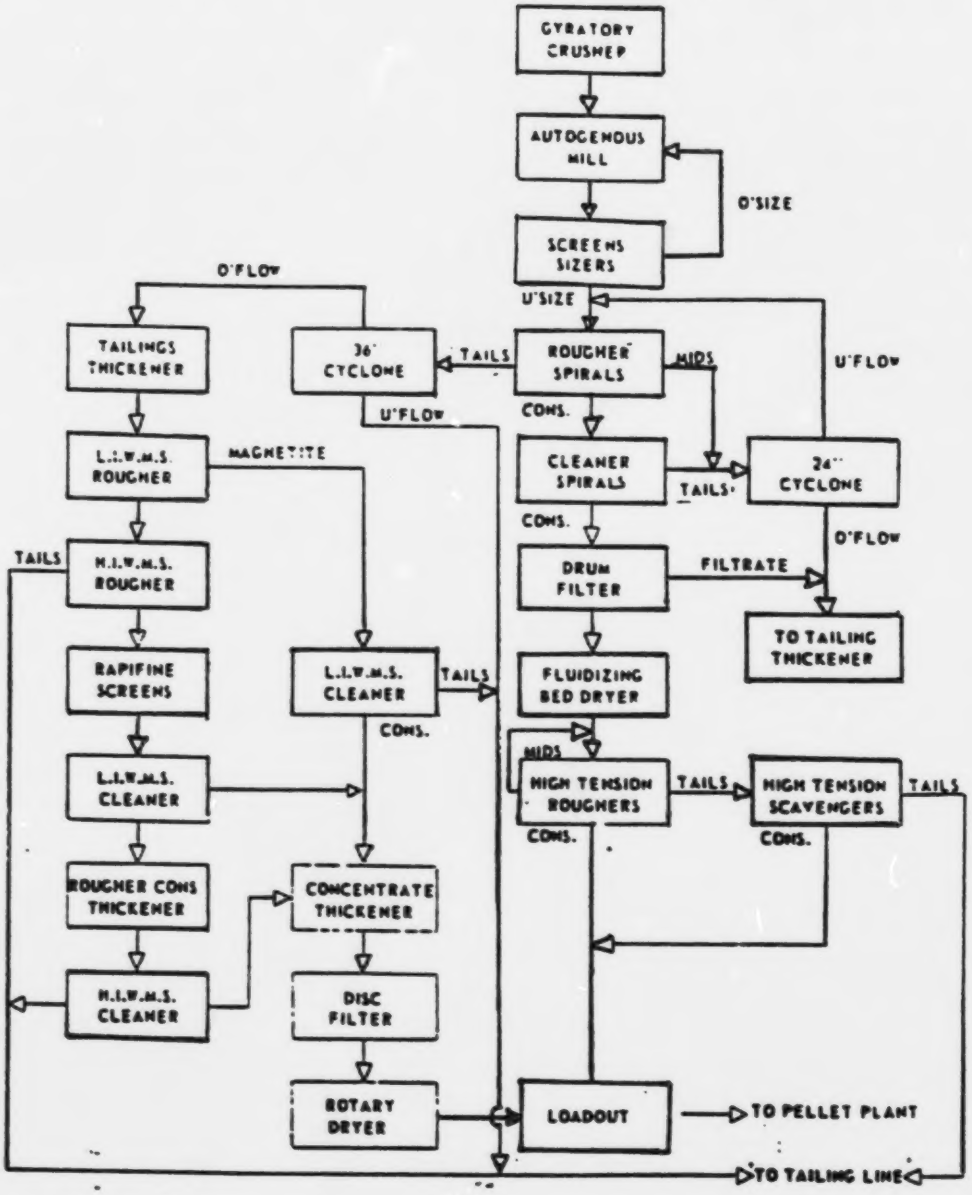
PRODUCT	wt % of product	total sample	sieve fraction (mesh)				
			+20	+65	+150	+270	-270
sizing screen undersize	100.0	100.0	7.2	45.3	31.1	8.6	7.6
rougher spiral middlings	3.6	8.5	1.8	5.3	1.0	.4	.0
rougher spiral tailings	46.0	31.3	4.3	19.1	4.3	2.2	1.4
rougher spiral concentrate	57.5	66.9	7.5	15.1	14.0	30.2	.1
cleaner spiral tailings	8.7	3.4	1.4	1.0	.7	.3	.1

	wt % of product	total sample	sieve fraction (mesh)						
			+20	+35	+65	+150	+270	+400	-400
cleaner spiral concentrate	48.8	63.5	.0	11.5	23.6	25.6	2.6	.1	.0

* reported as wt% of free grains entering spirals

APPENDIX N

Scully Concentrator
Flowsheet of the Plant


GYRATORY CRUSHER
AUTOGENOUS MILL
O'SIZE
SCREENS SIZERS
O'FLOW
U'SIZE
TAILINGS THICKENER
36" CYCLONE
TAILS
ROUGHER SPIRALS
MIDS
U'FLOW
U'FLOW
CONS.
L.I.W.M.S. ROUGHER
MAGNETITE
CLEANER SPIRALS
TAILS
24" CYCLONE
CONS.
O'FLOW
TAILS
H.I.W.M.S. ROUGHER
DRUM FILTER
FILTRATE
TO TAILING THICKENER
RAPIFINE SCREENS
L.I.W.M.S. CLEANER
TAILS
FLUIDIZING BED DRYER
CONS.
MIDS
L.I.W.M.S. CLEANER
HIGH TENSION ROUGHERS
TAILS
HIGH TENSION SCAVENGERS
TAILS
CONS.
CONS.
ROUGHER CONS THICKENER
CONCENTRATE THICKENER
H.I.W.M.S. CLEANER
DISC FILTER
ROTARY DRYER
LOADOUT
TO PELLET PLANT
TO TAILING LINE

Flowsheet of the Scully Concentrator.

AUTHORIZATION

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